COMPREHENSIVE ENERGY AUDIT REPORT

of

CHEMFAB ALKALIS LIMITED,

PONDICHERRY

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CHEMFAB ALKALIS LIMITED.

PONDICHERRY

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

1.0 INTRODUCTION

This section presents a summary of recommendations contained in the main report The main report presents a comprehensive and complete analysis and recommendations emerging from the detailed energy audit study of the unit. The study mainly pertains to auxiliary electricity and furnace oil consuming equipments.

2.0 PRODUCTION AND ENERGY CONSUMPTION PROFILE

A. Production Details

Plant produces basically caustic soda lye and chlorine, hydrochloric acid, hydrogen and sodium hypochlorite as by products. Details of installed capacities and actual production for the last 3 years are as shown below:-

Year	Caustic Soda lye (MT)		Hydrochloric acid 100% (MT)		Chlorine (MT)		Hydrogen (MCM)		Sodium hypo Chloride (MT)	
	Installed	Actual	Installed	Actual	Installed	Actual	Installed	Actual	Installed	Actual
1994-95	23725	16013 (67%)	8400	4591 (55%)	20860	13128 (63%)	3	1 4686 (49%)	1000	3123 (312%)
1995-96	23725	16233 (68%)	8400	5250 (63%)	20860	13337 (64%)	3	1.413 (47%)	1000	3123 (312%)
1996-97	31025	17163 (55%)	12730	6425 (50%)	27300	13904 (51%)	3	1.555 (52%)	2100	3485 (166%)

MCM = Million Cubic Meters

Production values are (net of disposal, consumption etc.,)

The actual production of caustic soda lye, hydrochloric acid, chorine and hydrogen vary between 50% to 70% of installed capacities due to power restrictions in all the 3 years.

B. *Energy Consumption*

Electricity, Furnace oil, hydrogen and diesel are the major sources of energy to the plant. Break-up of energy consumption for the last 3 years are as given below:

Year	Electricity Consumption Million kWh	Furnace oil Consumption kL	Specific electricity consumption (electrolysis) kWh/Mt
1994-95	4.7335	449	2442
1995-96	4.7582	408	2453
1996-97	5.1152	539	2485

It can be observed that there is a marginal increase in specific electricity consumption over the years. The auxiliary energy consumption is about 12.4% of the total electricity consumption.

3.0 SUMMARY OF ENERGY SAVINGS POTENTIAL

A summary table giving the potential savings and payback on investment is given below. List of retrofits and their suppliers addresses are given in Appendix -13/1.

Sl. No	Proposal	Annual Energy Savings					Cost of implemen-tation Rs.	Simple payback period Years
		(kWh)	Steam (Mt)	F O (kL)	DM water (m^3)	Cost Rs		
1	Electrical Systems	10296.5	-	-	-	46938	28500	0.61
2	Electric Drives	192913	-	-	-	331810	793280	2.39
3	Chilled Water System	562400	-	-	-	967300	6240000	6.5
4	Compressed Air System	184904	-	-	-	318034	520000	1.63
5	Steam Generation, Distribution & Utilisation	-	310.8	12.95	3950	348000	234000	0.67
6	Pumps & Blowers	176700	-	-	-	303700	718000	2.4
7	Lighting	22732	-	-	-	39099	149200	3.8
	Total	**1149945.5**	**310.8**	**12.95**	**3950**	**2354881**	**8682980**	-

The study shows that an annual electricity savings of about 11.49 lakh kWh (i.e Rs.19.78 lakh) which is about 18% of auxiliary consumption and an annual furnace oil savings of about 40 kL (i e Rs 2 37 lakhs) which is about 7.4% of furnace oil consumption can be achieved through implementation of energy efficiency improvement measures

Total energy savings (both furnace oil and electricity) by implementing the various measures are estimated at Rs 23.55 lakh per annum with an investment of Rs 133 6 lakh The savings potential and payback period calculations are based on the present cost of power and furnace oil. The saving potential and payback will increase with increase in energy cost.

4.0 ELECTRICAL SYSTEMS

A. HT & LT Bus Voltage Co-ordination

The measurement and analysis of 22 kV bus and 415 V bus voltage levels indicate that the bus voltages are maintained to the required voltages reducing the magnetic losses in system equipments which should be continued

B. Distribution Losses

Techno-economics of distribution losses in LT cables for various MCC's were computed(section 3 2 J).

(I) Shifting of 3 x 20 kVAr, 2 x 20 kVAr and 2 x 20 kVAr capacitors from main PCC bus to MCC - 3, MCC - 4 and MCC - 10 respectively.

In the event of SEB power failure, MCC-B panel caters to the essential loads through DG power. It is suggested to switch off the capacitors of 3 X 20 kVA (shifted from main PCC to panel) by interlocking with AMF panel when DG power is ON.

(ii) Installation of 95 kVAr capacitor across the main bus of MCC - 6 would improve the present p.f. from 0.85 to 0.98.

5.0 ELECTRIC DRIVES

A. *Use of Energy Efficient Motors*

Most of the motors of Cell house # 1 and common utilities should be replaced with energy efficient motors in phases Annual savings to the tune of 1.01 lakh kWh with a simple payback of 2 6 years can be realised on implementation of above measure (Section 4 2 -B).

B. *Star Mode Operation of Motors*

(i) Star Mode Operation

Sludge motor - B, Guard tower Pump and Air blower - B were found loaded below 30% and hence should be run in star mode Annual energy savings of 3796 kWh can be achieved without any installation cost (Section 4.2.C (i))

(ii) Auto-Delta Star Mode Operation

Reactor tank agitator and slurry tank agitators which are seldom loaded above 30% should be run in Auto Delta star mode operation This measure is expected to yield an annual energy savings of 3160 kWh with a simple payback period of 5 5 years (Section 4 2 C (ii))

C. *Replacement of Aluminium Blades with FRP Blades*

Cast aluminium blades should be replaced with FRP blades for all cooling tower fans The above retrofit is expected to reduce kW load on motors by atleast 25% due to FRP blades being light weight material Annual energy savings that can be realised is to the tune of Rs. 1.46 lakhs with a simple payback period of 2.13 years. (Section 4.2 -D).

6.0 CHLORINE COMPRESSORS AND LIQUEFACTION SYSTEM

The operation and performance of the chlorine compressors and freon compressors have been studied and the loading pattern and operation parameters have been analysed.

A. Loading Pattern

Sl. No.	Item	Rated kW (Each)	Actual kW (Each)	% Loading
1.	Chlorine Compressor			
	A	90	78	86.7
	C	90	75.6	84.0
2.	Freon Compressor			
	A	110	79.5	72.3

B Operational Analysis of Freon Compressor.

Compressor No.	Current (Amps)	Suction pressure (psi)	Delivery pressure (psi)	Rated current (Amps)
A	151 6	36.2	222.4	185
B	90.5	34.5	195.4	185
% Variation	40.3	4.7	12.1	-

It is observed that for a 4% variation in suction pressure and 12% variation in delivery pressure, the current (Amps) drawn by the motors of the 2 freon compressors vary to the extent of 40%.

The difference in loading in the freon compressors is mainly due to compressor unloading at lower demand as per process requirement.

7.0 CHILLED WATER SYSTEM

A. Chilled water supply to user areas should be modified by providing two separate lower head pumps. This measure is expected to result in an annual energy savings of Rs.34,400/- with a simple payback period of 7 years. (Section 7.2-E).

B Replacement of existing vapour compression machine by vapour absorption machine should be considered as a long term measure. This measure results in an annual energy savings of 5,42,400 kWh (i.e.Rs.9,32,900/-) with a simple payback period of 6.4 years. (Section 7.2 -E).

8.0 COMPRESSED AIR SYSTEM

The plant has five air compressors During normal hours two compressors for instrument air supply and one compressor for chlorine unloading, operate. The other two compressors are on standby duty

A. *Free Air Delivery Test*

Free Air Delivery test was conducted on all the compressors and the results indicate that the actual FAD figures have been found to be far lower than the rated figures. Only compressor E (new machine) has been found alright. The other compressors should be taken up for thorough mechanical overhaul and rectification work, so that FAD performance improves

Energy savings achieved by improvement in FAD are estimated to be 153696 kWh/year (Rs.264356/year). The cost of implementation is Rs 4,00,000/- with a simple payback period of 1.5 years. (Section 8.2).

B. Compressed Air Leakage

Compressed air leakage inspection was carried out and the details of identified leaks have been listed and recorded for corrective action. (Section 8 2).

C. Application of Flat Belts in Lieu of V-belts in Motor Drives

The following tabulation gives a summary of energy savings which could be achieved by changing over to flat belts from V-belts.

Item	Annual Savings	
	kWh	Rs.
Air compressor - A	3154	5424
Air compressor - C	3427	5895
Air compressor - D	3406	5858
Air blower - B	319	549
H_2 blower - A	994	1710
H_2 compressor - B	7416	12756
H_2 compressor - C	12492	21486
TOTAL	**31208**	**53678**

The above change will involve a cost of implementation of Rs.1,20,000 with a simple payback period of around five years.

9.0 STEAM GENERATION, DISTRIBUTION AND UTILISATION

The plant has one boiler of rated capacity 2000 kg/h and a steam generation pressure of 10 5 kg/cm^2.

A. *Boiler Trial*

Boiler trial was conducted and the important parameters observed for efficiency evaluation before and after excess air control are tabulated below.

Sl No	Particulars	Before Excess Air Control	After Excess Air Control
1	Av.% CO_2	8.5	11.5
2.	Av.flue gas temperature	188^{0}C	190^{0}C

It can be observed that % CO_2 has improved considerably from 8.5% to 11.5% after adjusting the intake of excess air.

Efficiency of boiler before and after excess air control works out to approximately 82% and 85% respectively (Section 9 3-A [a])

B. *Energy Savings by Excess Air Control*

Regular monitoring of exit flue gases (% CO_2 and temperature) goes a long way towards reduction of energy consumption

Implementation of this measure is expected to result in energy savings to the tune of 12952 litres of furnace oil per year The value of savings amounts to Rs.72531 per year with a simple payback period of 0 7 year. (Section 9 3-A [b]).

C. *Energy Savings by Recovery of Heat in Condensate*

By systematically collecting and transporting the condensate water to the feed water system, the potential feed water temperature will rise and it will replace equivalent quantity of DM water. Implementing this measure will lead to annual DM water savings if 3950 m^3 The cost of implementation will be Rs 1,50,000 and the simple payback period will be 0 8 year (Section 9.3-A [c]).

D. Arresting Distribution Steam Leakages

By implementing this proposal, steam savings of 174.8 tons per year could be achieved valued at Rs.43,700/- per year. The cost of implementation would be Rs 25,000/- and the simple payback period would be 0.57 year. (Section 9 3-B [a])

E. Rectifying Uninsulated Valves, Flanges, etc.

Uninsulated valves and flanges should be rectified resulting in steam savings of 136 t/year valued at Rs 34,000/year. The cost of implementation would be Rs.8640/- with a simple payback period of 0 25 year. (Section 9.3-B [b]).

10.0 PUMPS & BLOWERS

A The existing inefficient thermic fluid circulation pump in concentration plant should be replaced by new one. This measure is expected to result in annual energy saving of Rs 52,000/- with a simple payback of 2 years (Section 10 2-C)

B 11 number of inefficient pumps identified should be replaced by efficient ones This measure is expected to result in annual energy saving of 146460 kWh (i e. Rs 2,51,700/-) with a simple payback of 2 5 years (Section 10.2-D)

11.0 LIGHTING SYSTEMS

A. General

1. Periodic cleaning of luminaires should be carried out to get maximum lumens per watt consumed Plant personnel are already carrying out this activity periodically.

2. One fluorescent tube of 2 x 40 W twin fluorescent tube is already removed by plant personnel for energy savings But the choke is in circuit consuming around 4 - 6 watt. All such chokes can be disconnected from circuit.

B. *Energy Efficient Lighting*

I. Use of reduced voltage through exclusive lighting transformer is expected to yield an annual energy saving of Rs 22,978/- with a simple payback period of 3 7 years. (Section - 12 3-B(I))

II. Chokes for fluorescent tube fixtures shall yield an annual energy savings of Rs 1,6121/- with a simple payback period of 3 98 years (Section - 12 3-B(II)).

MAIN REPORT

CHEMFAB ALKALIS LIMITED, PONDICHERRY

COMPREHENSIVE ENERGY AUDIT REPORT

1.0 INTRODUCTION

This report presents the findings of the Energy Audit of Chlor Alkali plant of M/s.Chemfab Alkalis Limited, located at Pondicherry

A detailed study was carried out in the following areas to identify energy saving opportunities

- Electrical System
- Electrical Motors
- Steam Generation, Distribution & Utilisation
- Chilled Water and Freon Systems
- Pumping System
- Air Compressors
- Cooling Towers
- Chlorine Blowers and Compressors
- Thermic Fluid Heating System
- Lighting System

During the study, every attempt was made to understand the operational features and working of the project in the proper perspectives.

The study analysis included taking measurements of energy related parameters using various portable instruments.

There is a high level of awareness in the Plant Management on the need to conserve energy. Several steps are being continuously initiated by the Plant Management on its own in this direction, which has resulted in significant reduction in overall energy consumption over the last few years.

This report presents the analysis, findings and recommendations for achieving energy savings.

2.0 PRODUCTION AND ENERGY CONSUMPTION PROFILE

2.1 PRODUCTION DETAILS

Plant produces basically caustic soda lye and chlorine, hydrochloric acid, hydrogen and sodium hypochlorite as by products. Details of installed capacities and actual production for the last 3 years are as shown below:-

Year	Caustic Soda lye (MT)		Hydrochloric acid 100% (MT)		Chlorine (MT)		Hydrogen (MCM)		Sodium hypo Chloride (MT)	
	Installed	Actual	Installed	Actual	Installed	Actual	Installed	Actual	Installed	Actual
1994-95	23725	16013 (67%)	8400	4591 (55%)	20860	13128 (63%)	3	1.4686 (49%)	1000	3123 (312%)
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MCM = Million Cubic Meters

Production values are (net of disposal, consumption etc ,)

The actual production of caustic soda lye, hydrochloric acid, chorine and hydrogen vary between 50% to 70% due to power restrictions in all the 3 years.

2.2 ENERGY SOURCES

Electricity, Furnace oil, hydrogen and diesel are the major sources of energy to the plant. Break-up of energy consumption for the last 3 years are as given below·

Year	Electricity Consumption Million kWh	Furnace oil Consumption kL	Specific electricity consumption kWh/Mt
1994-95	4.7335	449	2442
1995-96	4.7582	408	2453
1996-97	5.1152	539	2485

It can be observed that there is a marginal increase in specific electricity consumption over the years 'Month-wise specific electricity consumption for electrolysis, auxiliaries and specific furnace oil consumption for the period Apr'96-Mar'97 are given in Appendix - 2/1

3.0 ELECTRICAL SYSTEM

3.1 FACILITY DESCRIPTION

A. General

The company's main source of electricity is from Pondicherry State Electricity Board through a single circuit 110 kV transmission line. 110 kV/22 kV receiving station is located within the plant layout and houses one main power transformer. This main power transformer distributes power to Cell house #1 rectifier transformer, Cell house #2 rectifier transformer and 22 kV/415V auxiliary transformer though 22 kV HT panel located at HT room. The details of the transformer are given below:

DETAILS OF TRANSFORMERS

Details	Main 110 kV transformer	Rectifier I transformer	Rectifier II transformer	Auxiliary transformer
Capacity MVA	10/16	5 313	8.450	2
Voltage Ratio kV	110/22	22/0 1362	22/0.3603	22/0 415
Make	Hack bridge Hewittic EASUN	BHEL	BHEL	HHE
Type of cooling	ONAN/ONAF	OFWF	OFWF	ONAN
Primary rated current (Amp)	52 5/84	139.4	221.75	52.5
Secondary rated current (Amp)	262 7/420.4	15874	9543	2666.9
Vector Group	Dyn 11	-	-	Dyn 11
Rated Frequency	50	50	50	50
OLTC	Yes	Yes	Yes	No
Mode of operation	Independent	Independent	Independent	Independent

B. Electricity Consumption Data

The power requirement of the plant is around 7900 kVA (contract demand is 8000 kVA). Monthly consumption data for 1996-97 is given in Appendix -3/2.

(i) HT Power Distribution

22 kV power supply is distributed to cell house #1 Rectifier transformer, Cell house #2 Rectifier transformer and to 22 kV/415V auxiliary transformer for auxiliary power distribution.

(ii) LT Power Distribution

Auxiliary power at 415 V is distributed to various MCC panels located close to load centres.

(iii) Power Capacitors

Fifth Harmonic filter of 6087 kVAr capacitors in series with 340 kVAr reactor is installed at 22 kV bus for filtering efficiently harmonics and for power factor improvement.

HT capacitor bank of 2100 kVAr in series with 126 kVAr reactor is also installed at 22 kV bus for power factor improvement only

LT capacitors are provided at PCC panel and at MCC panel directly to the motor feeders. The details of capacitor installed is given in Appendix -3/3.

3.2 OBSERVATION, ANALYSIS AND FINDINGS

A. Measurement

Measurements were carried out using portable power and demand analyser at the Main HT and LT incoming panels. Necessary details with respect to electrical parameters were also collected from log registers.

B. Main System Parameters

The measurements of load parameter of incoming 110 kV system was carried out on 13/14th June'97 using CT & PT terminals of incomer panel.

The general consumption pattern, variation of MD and power factor has been shown in Appendix -3/1

The incoming voltage, load current, frequency, pf, kW, kVA and kVAr load with reference to time is plotted in the graphs represented in Appendix - 3/1 a - g

C. 22 kV Incoming System Parameters

22 kV system parameter measurements (2 hours each) to Cell house #1, Cell house #2 and total 22 kV incoming was carried out on 16/17th June'97 using CT & PT terminals of the respective HT panels.

The general consumption pattern of system voltage, current, Cos ϕ, kW, kVA are represented in Appendix -3/4, 3/5 & 3/6 for cell house #1, cell house #2 and 22 kV incomer supply respectively.

D. Transformer Load Management

110 kV main transformer secondary voltage is maintained between 21.0 kV to 22 kV. On load tap changer is operated manually to maintain the above voltage. The tap changing is carried out whenever the cell house #1 and #2 process voltage and current varies above set values.

The Cell house #1 and Cell house #2 rectifier transformer are provided with OLTC and they are operated in auto mode.

All the transformer loading is calculated and represented below.

Transformer	Load in Amps	Actual load kVA (measured)	Annual N/L loss kWh	Annual full load loss kWh	Total losses kWh/y	% loading of transformer
110 kV main transformer (12th June'97)	39 9 (HT)	6650	106434 0	257826.8	364260 8	66 5
Rect Trfr. # 1 (17th June'97)	105 4 (HT)	4080	82624 3	579941 7	662566 0	76 8
Rect. Trfr. # 2 (16th June'97)	78 8 (HT)	2960	104068 8	135516 6	239585 5	35 0
415 V Aux Trfr (12th June'97)	1479 (LT)	1029	23652 0	31930 7	55582 7	51 5

Note: Loss load factor is assumed to be as 0.85 and utilisation factor to be as 0 90

The power factor of loads were observed to be between 0.97-0.99, minimising I^2R losses of the transformers.

E. Optimum Bus Voltage Co-ordination

(i) 110 kV/22 kV Bus Voltage System

110 kV main transformer voltage is well maintained between 98 kV - 103 kV by the plant operating personnel. This is a good practice which yield system benefit like.

- Reduction in kVA MD
- Reduction in distribution losses (mainly due to reduced magnetic losses in motors)
- Improvement in system PF and reduced demand for reactive power drawn from grid
- Reduction in kVA loading of transformer and hence losses

(ii) LT Bus Voltage System

The off load tap changer setting of auxiliary transformer is observed to be maintained at tap 2 The secondary voltage levels were measured to be in the range of 392-411 volts to drive motors rated at 415 V. LT power measurements was carried out for total auxiliary system at PCC panel on 12/13th June'97 shows the general consumption pattern are represented in Appendix - 3/7.

F. Power Factor Management

The monthly average power factor of the plant has varied between 0.97 to 0.99 during last year. LT capacitors of 4.95 kVAr is installed on 22 kV bus.

G. Distribution Losses

The plant has made use of multiple runs of cables of adequate sizes from PCC to MCC. The design of providing optimum no. of runs and adequate cable size help in keeping the voltage drop and distribution losses to the lowest minimum. Loading pattern of all MCC incomer cables were measured at PCC outgoing. The distribution losses in cables between PCC and MCC's were calculated and is presented in Appendix - 3/8 and 3/8 a and 3/8 b.

The Power factor of MCC - 3 can be improved from 0 77 to 0 97 , by shifting 3 x 20 kVAr capacitors from main PCC bus to MCC-3 main bus. This measure on implementation shall help in reduction of distribution loss in cable to an extent of 3155.5 kWh per annum and with immediate payback

Similarly, improvement in p.f. from 0 77 to 0 94 for MCC- 4 can be attained by shifting 2 x 20 kVAr capacitors from main PCC bus to MCC - 4 main bus. A saving of 2580 kWh per annum is realised on implementation of this measure with marginal investment cost and immediate payback.

Improvement in Power factor from 0.89 to 0.98 on MCC-10 main bus can be attained by shifting 2 x 20 kVAr capacitor from main PCC bus to MCC-10 main bus. This measure on implementation, savings to the tune of 2115 kWh per annum can be realised with marginal investment cost .

With the above arrangements a total of 45 kVAr capacitor on main PCC LT bus will remain still in the circuit.

MCC - 6 power factor can be improved from 0.85 to 0.98 by installing a total of 95 kVAr capacitor across the main bus. This additional capacitors shall release around 35 kVA demand on the system. This measure on implementation yield annual saving of Rs.33434/- with investment cost of Rs.28,500/- and payback period being 0.85 years.

3.3 RECOMMENDATIONS

A. HT & LT Bus Voltage Co-ordination

The measurement and analysis of 22 kV bus and 415 V bus voltage levels indicate that the bus voltages are maintained to the required voltages reducing the magnetic losses in system equipments which should be continued.

B. Distribution Losses

Techno-economics of distribution losses in LT cables for various MCC's were computed(section 3 2 G).

(I) Shifting of 3 x 20 kVAr, 2 x 20 kVAr and 2 x 20 kVAr capacitors from main PCC bus to MCC - 3, MCC - 4 and MCC - 10 respectively shall yield in savings as below :

Annual Energy savings	=	7851 4 kWh
Annual Cost saving	=	Rs.13504 /-
Cost of implementation	=	Marginal
Simple Payback period	=	Immediate

(ii) Installation of 95 kVAr capacitor across the main bus of MCC - 6 would improve the present p.f. from 0 85 to 0.98. This measure on implementation shall yield annual savings as below :

Annual Energy savings	=	2445.1 kWh
Annual Cost saving	=	Rs 33,434/-
Cost of implementation	=	Rs 28,500/-
Simple Payback period	=	0 85 years

3.4 SUMMARY OF POTENTIAL SAVINGS

Sl No	Recommendations	Annual Energy Savings		Investment required Rs.	Simple Payback period Year
		kWh	Rs		
1.	Distribution losses in MCC-Feeders	10296 5	46938	28500	0 61
TOTAL		**10296.5**	**46938**	**28500**	**0.61**

4.0 ELECTRIC DRIVES

The study covers LT induction motors coupled to pumps, blowers, air compressors, hydrogen compressors, chlorine compressors, etc. used for production of sodium hydroxide

4.1 FACILITY DESCRIPTION

A. Cell House - 1

Cell house - 1 is housed with 12 cells producing sodium hydroxide by electrolysis process using the membrane technology. Various motors ranging between 2.2 kW to 22 kW drive the auxiliaries for the process. All the drives have 100% standby

B. Cell House - 2

Cell house - 2 is also housed with cells producing sodium hydroxide by membrane technology. Almost all drives in cell house # 2 also have 100% standby

C. Utilities

Air compressors, cooling water system, DM water system and other auxiliaries form the utility equipments for the electrolysis process.

4.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Loading Pattern of Motors

The operating parameters like motor load in kW, ampere loading and PF of operation have been measured using the hand held power analyser. The loading pattern of total plant LT motors of rating 2.2 kW and above were measured and the same are given in Appendix - 4/1 (MCC wise).

(i) Cell House # 1 Motor Drives

* The depleted brine pump B was loaded to 65.6%
* Sodium hypo circulation pump A was loaded to 57 4%
* Dechloronated brine pump A was loaded to 70%
* Secondary brine pump A was loaded to 61 3%
* Air blower - B loading was around 24% and also the gaurd tower pump loading at 27.8%.
* Chlorine and hydrogen blowers were loaded around 62% and 44% respectively
* All the process pumps were found loaded optimally
* The operating pf of all the drives loaded above 70% was found to be above 0.70 lag.

(ii) Cell House # 2 - Motor Drives

* Lean brine pump of 3.7 kW was loaded to 86%
* Catholyte pumps, vacuum pump and pure brine pump motors were also loaded optimally.
* All the motors in cell house # 2 were found to be energy efficient motors operating with p f above 0 60 and the loading of motors found to be above 70%.

(iii) Liqchlor & Hydrogen Filling System

* Freon compressor, chlorine compressor chilled water compressors were all found to be energy efficient motors with good optimal loading
* Chilled water pump A of 18.5 kW was loaded to 88%.
* The hydrogen compressors A, B and C used for filling cylinders and manifolds were loaded to 44, 69 and 65% respectively.
* All the operating p.f of all the above motors was found above 0.85 lag

(iv) Concentration and Boiler Plant

* Main cooling water pump B of 90 kW was loaded to 74%.
* Boiler water feed pump and oil pump were loaded to 88.5% and 64.2% respectively
* Concentration plant thermic fluid pump of 37 kW was loaded optimally

(v) Barium Sulphate Plant

* All the slurry tank agitator were loaded below 20%.
* Product slurry pump was loaded to 87% with operating p.f. of 0.84 lag

B. Use of Energy Efficient Motors

Some of the plant auxiliary drives (both standard motors and energy efficient motors) have been rewound more than once. Such motors which are rewounded more than 2 times needs to be reviewed for potential savings by use of energy efficient motors.

Most of the motors of Cell house # 1 were identified to be replaced with energy efficient motors. In addition motors used in common utilities were also identified for replacement with energy efficient motors Techno-economics of these motors are presented in Appendix - 4/2a and a sample calculation for replacement with energy efficient motor is given in Appendix - 4/2.. The implementation of this measure has a potential energy saving of 1.01 lakh kWh per annum.

C. Star Mode Operation of Motors

(i) Star Mode Operation

Sludge motor - B, Gaurd tower Pump and Air blower - B were found loaded below 30%. These motors have to be run in star mode to improve the operating p.f. and operating efficiency of the drive. Annual energy savings of 3796 kWh can be achieved without any installation cost

(ii) Auto-Delta Star Mode Operation

Reactor tank agitator and slurry tank agitators which are seldomnly loaded above 30% are recommended to be run in Auto Delta star mode operation. Auto delta star starters change over to either delta or star mode depending on the load current. This measure on implementation shall yield annual energy savings of 3160 kWh

D. Replacement of Aluminium Blades with FRP Blades

It is proposed to replace the cast aluminium blades with FRP blades for all cooling tower fans. The above retrofit is expected to reduce kW load on motors by atleast 25% due to FRP blades being light weight material. Energy savings of 0.91 lakh kWh can be realised on implementation of this measure. Techno-economics details are given in Appendix - 4/4. Addresses of manufacturers of such systems are given in the chapter on retrofits.

4.3 RECOMMENDATIONS

A. Use of Energy Efficient Motors

Most of the motors of Cell house # 1 and common utilities should be replaced with energy efficient motors in phases On Implementation of above measure annual savings which can be realised is given below : (Section 4.2 B).

Annual energy savings	=	1,00,517 kWh
Annual cost saving	=	Rs.1,72,889 /-
Cost of implementation	=	Rs 4,50,080 /-
Simple payback period	=	2 6 years

B. Star Mode Operation of Motors

(i) Star Mode Operation

Sludge motor - B, Gaurd tower Pump and Air blower - B were found loaded below 30% and hence should be run in star mode. Annual energy savings of 3796 kWh can be achieved without any installation cost. (Section 4.2.C (i))

Annual energy savings	=	3796 kWh
Annual cost saving	=	Rs.6529/-
Cost of implementation	=	Nil
Simple payback period	=	Immediate

(ii) Auto-Delta Star Mode Operation

Reactor tank agitator and slurry tank agitators which are seldomnly loaded above 30% should be run in Auto Delta star mode operation. This measure on implementation shall yield annual energy savings as below: (Section 4 2 C.(ii)).

Annual energy savings	=	3160 kWh
Annual cost saving	=	Rs 5435/-
Cost of implementation	=	Rs.30,000/-
Simple payback period	=	5 52 years

C. Replacement of Aluminium Blades with FRP Blades

Cast aluminium blades should be replaced with FRP blades for all cooling tower fans. The above retrofit is expected to reduce kW load on motors by atleast 25% due to FRP blades being light weight material. Annual energy savings can be realised on implementation of this measure is as follows : (Section 4.2.D).

Annual energy savings	=	85,440 kWh
Annual cost saving	=	Rs 1,46,957/-
Cost of implementation	=	Rs 3,13,200 /-
Simple payback period	=	2.13 years

4.4 SUMMARY OF POTENTIAL SAVINGS

	Proposal	Annual energy savings		Investment required	Simple payback period
		kWh	Rs.	Rs	Years
1.	Use of energy efficient motors	100517	172889	450080	2 6
2.a	Star mode operation of motors	3796	6529	-	-
b	Auto delta star mode of operation	3160	5435	30000	5.52
3	Replacement of aluminium blades by FRP blades	85440	146957	313200	2.13
	Total	**192913**	**331810**	**793280**	**2.39**

5.0 CONCENTRATION PLANT

5.1 FACILITY DESCRIPTION

The concentration plant is used to concentrate 33% caustic lye to 48% caustic lye. The evaporation of caustic lye is carried out in two pots. Pre-concentration to around 38% takes place in a falling film evaporator. Hytherm oil 500 is used as a thermic fluid. The characteristics of hytherm oil 500 is given in Appendix - 5/1.

5.2 PRODUCTION AND ENERGY CONSUMPTION PROFILE

Furnace oil and hydrogen are used as fuel. 48% caustic production, furnace oil consumption, hydrogen consumption and running hours for the last 4 years are given below:

Year/ Month	Production (48%) MT	F.Oil kL	Hydrogen. cum * 1000	R. Hrs
1993-94	6270.33	205.2	-	6501.36
1994-95	7168.11	216 96	415.86	7150.45
1995-96	7019.8	188.64	1771.77	7355.4
1996-97	7823.48	344 04	1415.18	7188.61

Monthly production and energy consumption details are given in Appendix - 5/2.

5.3 OBSERVATIONS, ANALYSIS & FINDINGS

A. Estimation of Efficiency of Thermic Fluid Heater

The observed process parameters and thermic fluid heater parameters are given in Appendix - 5/3 The efficiency of thermic fluid heater has been worked out by indirect heat loss method During the trial, input caustic rate was 4.5 t/h and ratio of oil flow rate to hydrogen flow rate was 70:30. Measured % CO_2 in exit flue gases was 4% This corresponds to percentage oxygen of 2.22%. The above values indicate the optimum value of excess air. Based on the measured parameters thermal efficiency of the thermic fluid heater is worked out to be 81.77%.

B. *Insulation Aspects*

The measured surface temperatures of Pot-I and Pot-II were in the range of 39°C to 42 °C. Hence, the insulation provided is adequate. It is observed that both supply and return thermic fluid line valves are uninsulated. They should be insulated at the earliest.

C. *Estimation of Excess Hydrogen Availability as a Fuel*

Month-wise hydrogen generation and utilisation pattern for the period Apr-Mar,97 is given in Appendix - 5/5

The summary of utilisation pattern is given below

Year	Parameter	Value X 1000 m^3	%
1996-97	<u>Production</u>		
	Hydrogen Generation	5024	100
	<u>Consumption</u>		
	Thermic Fluid Heater	1414	28
	Hydrogen Bottling plant	1554	31
	Hydrochloric acid plant	715	14
	Vent	1341	27

It may be seen as much as 27% of the hydrogen generation is vented out. Th exists a good scope for utilisation of this vent hydrogen as a fuel for vapour absorption machine. This aspect has been discussed in Chapter 7 0

6.0 CHLORINE COMPRESSORS AND LIQUEFACTION SYSTEM

6.1 FACILITY DESCRIPTION

Dry chlorine gas is compressed in acid ring chlorine compressor to a pressure of 3.5 kg/cm^2 The dry compressed, filtered chlorine gas is then condensed in the chlorine condenser and is liquefied by using Freon. The liquid chlorine at a temperature of - 7°C flows to storage tanks.

The installed ratings and numbers of chlorine compressors and Freon compressors are tabulated below :

Sl No.	Item	Rated kW (Each)	Actual kW (Each)
1.	Chlorine compressor		
	A	90	78
	C	90	75.6
2	Freon compressor		
	A	110	79.5

6.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Matching of Drive and Driven Equipment

Based on the design flow and head, connected loads of drives have been observed to be in conformity with the requirement.

B. Loading Pattern

Sl No	Item	Rated kW (Each)	Actual kW (Each)	% Loading
1.	Chlorine Compressor			
	A	90	78	86.7
	C	90	75.6	84.0
2.	Freon Compressor			
	A	110	79.5	72.3

Detailed measured values are given in Appendix - 4/1.

C. Operational Analysis and Assessment

Detailed observations conducted on chlorine compressors are given in Appendix - 6/1.

Observations conducted on Freon compressors are given in Appendix - 6/2.

Observations conducted on chlorine liquefaction condenser are given in Appendix - 6/3.

The average Freon compressor parameters are as below :

Compressor No.	Current (Amps)	Suction pressure (psi)	Delivery pressure (psi)	Rated current (Amps)
A	151.6	36.2	222 4	185
B	90.5	34.5	195 4	185
% Variation	40.3	4.7	12.1	-

It is observed that for a 4% variation in suction pressure and 12% variation in delivery pressure, the current (Amps) drawn by the motors of the 2 Freon compressors vary to the extent of 40%

Freon compressor A draws 151 6 amps current, while Freon compressor B draws only 90.5 amps. This difference in loading is mainly due to compressor unloading at lower demand as per process requirement

7.0 CHILLED WATER SYSTEM

7.1 FACILITY DESCRIPTION

There are two numbers of chilled water machines (115 TR capacity) of which one acts as a standby.

7.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Operational Features

Typical observations of chilled water inlet, outlet temperatures and pressures, condenser inlet, outlet temperatures and pressures have been tabulated in Appendix - 7/1

It is observed that pressure drop across condenser is higher at 1.5 kg/cm^2g. Normally allowed pressured drop is around 1 kg/cm^2g. Hence, periodical cleaning of condenser should be undertaken to keep pressure drop within around 1 0 kg/cm^2g

B Performance Evaluation

Quantification of tons of refrigeration has been carried out by measuring actual chilled water flow and temperature drop across chiller The actual capacity works out to around 128TR Specific power consumption works out to 0.75kW/TR Details are given in Appendix-7/2.

C. *Use Load Assessment*

The estimation of user load is as follows

User Area	TR
98% acid cooler (Plant-I)	40
98% acid cooler (Plant-II)	39
78% acid cooler (Plant-I)	5 5
78% acid cooler (Plant-II)	8
Sodium hypo load	14
Acid circulation (in hypo)	7
Chlorine cooler (Plant-I)	5
Chlorine Cooler (Plant-II)	8
Total	127

Calculation details are given in Appendix - 7/3

D. *Insulation Aspects*

It is observed that the following valves are uninsulated in the distribution network.

i 3 nos of valves in the chilled water pump discharge line

ii. 4 nos. of valves in the chilled water return line of 98% sulphuric acid coolers

The above valves need to be insulated at the earliest

E *Energy Savings by Reduced Pressure in Chilled Water Pump*

It is observed that chilled water pump discharge pressure is around 3 8 kg/cm^{2}g and 3 1 kg/cm^{2}g after the chiller Considering a maximum pressure drop in 98% Sulphuric acid coolers to be around 1 0 kg/cm^{2}g, chilled water supply pressure at 15m would suffice Also, considering a maximum pressure drop of 1 0 kg/cm^{2}g in 78% acid coolers and hypo coolers, chilled water supply pressure at 25 m would suffice. Based on the measured values of flows, it is preferable to have two separate pumps of capacity 50m^3/h, 15m head and 25 m^3/h, 20m head Implementation of this measure involves provision of a separate cold chilled water storage tank and hot well supply pump of capacity 75m^3/h, 12m head

This measure results in annual energy savings of Rs. 34,400 with a simple payback period of 7 years. Details are given in Appendix - 7/4.

F. ***Replacement of Chiller Compressor by Vapour Absorption Refrigeration Machine***

There exists a good scope for application of vapour absorption refrigeration machine in the place of vapour compression machine. A double effect machine of 140 TR capacity would suffice. Existing excess hydrogen available can pre-dominantly be used as a fuel supplemented by Furnace Oil The estimated hydrogen requirement is about 154 m^3/h. The average hourly hydrogen vented for the period Apr-Mar,97, indicates that only hydrogen can meet the needs of the fuel for about 9 months and hydrogen supplemented by furnace oil for the rest 3 months The system requires vapour absorption machine and dual fuel burner All the existing auxiliaries for the vapour compression machine remains the same for the new system

Implementation of this measure results in annual energy savings of 5,24,400 kWh(i e Rs 9,32,900/-) At an estimated investment of Rs 60,00,000/-, it works out to a simple payback of 6 4 years This proposal can be considered as a long term measure Details are given in Appendix - 7/5.

7.3 RECOMMENDATIONS

A. Chilled water supply to user areas should be modified by providing two separate lower head pumps This measure is expected to result in an annual energy savings of Rs 34,400 with a simple payback period of 7 years (Section 7.2-E)

Annual energy savings	=	20,000 kWh
Cost of energy savings	=	Rs. 34,400/-
Cost of implementation	=	Rs. 2,40,000
Simple payback period	=	7 years

B Replacement of existing vapour compression machine by vapour absorption machine should be considered as a long term measure This measure results in an annual energy savings of 5,42,400 kWh (i.e.Rs.9,32,900/-) with a simple payback period of 6 4 years. (Section 7.2 -E)

Annual energy savings	=	5,42,400 kWh
Cost of energy savings	=	Rs 9,32,900/-
Cost of implementation	=	Rs 60,00,000/-
Simple payback period	=	6.4 years

7.4 SUMMARY OF POTENTIAL SAVINGS

Sl. No	Proposal	Annual Savings		Cost of implementation Rs	Simple payback period Years
		Energy kWh	Cost Rs		
1	Provision of separate lower head pumps	20,000	34,400	2,40,000	7
2	Replacement of vapour compression machine by vapour absorption	5,42,400	9,32,900	60,00,000	6 4
	Total	**5,62,400**	**9,67,300**	62,40,000	6.5

8.0 COMPRESSED AIR SYSTEM

8.1 FACILITY DESCRIPTION

The plant has 5 air compressors, out of which one compressor installed in the chilled water and chlorine compressor area has just been commissioned and is under observation.

The compressed air is consumed in two different applications -

a Instrumentation system of entire plant
b. Unloading of chlorine from main tanks to cylinders.

The compressor specifications are tabulated below

Compressor	Type	Make	Rated FAD m^3/min	Rated kW	Qty. (Nos.)
KHOSLA VYDT	Reciprocating 2 stage	KHOSLA	2 63	22	5

During normal operating hours two compressors for instrument air supply and one compressor for chlorine unloading, operate The other compressors are on stand by

8.2 OBSERVATIONS, ANALYSIS & FINDINGS

A. Free Air Delivery Test

FAD test was conducted to assess the output of all the compressors:

Sl. No.	Compressor	Rated FAD m^3/min.	Actual FAD m^3/min	Remarks
1	A	2.63	1 13	Suction velocity method
2	B	2.63	0 91	Suction velocity method
3	C	2.63	0.91	Suction velocity method
4	D	2.63	0.16	Pump up method
5	E	2.63	2.62	Pump up method

The FAD details are given in Appendix - 8/1. The actual FAD figures have been found to be far lower than the rated figures. It appears the mechanical condition of the compressors is not satisfactory and the compressors are due for major overhaul and improvement in capacity The new air compressor no.E is good in FAD performance and the actual FAD value is close to the rated value.

Savings achievable by improving FAD is given in Appendix - 8/2.

B. Specific Energy Consumption

The specific energy consumption depends on the type of compressor, capacity, operating pressure and amount of free air delivered The specific energy consumption of the compressors was estimated and tabulated as below

Compressor	Actual FAD m^3/hr	Actual kW	kW/100 m^3/hr	Air pressure kg/cm^2
A	67 8	13 4	19 8	6 4
C	54 6	14.28	26 2	6 4
D	69 4	14 19	20 4	8 4

C. Loading Pattern of Compressor Motors

The air compressor motors were studied for loading The following table gives loading details.

Compressor	Application area	Rated kW	Actual kW	% loading	Air Pressure kg/cm^2
A	Instrument Air	22	13 14	59 7	6 4
C	Instrument Air	22	14.28	64 9	6.4
D	Chlorine unloading	22	14.19	64.5	8 4

D. Compressor Loading/Unloading Pattern

Out of the 5 Nos. Compressors, only two numbers (viz., compressor A & compressor D) were found to be unloading after reaching the set maximum pressure. The unloading operation is highlighted in the following tabulation:

Compressor	Pressure kg/cm^2		Unloading time (secs)	kW during unloading	% of rated kW
	Min.	Max			
A	6	6.4	50	4.29	19.5
D	8	8.4	46	-	-

It is observed that the ratio of unloading kW to rated kW and unloading kW to actual loading kW are 19 5% and 32.6% respectively.

The instrument air pressure at the point of instrument operation is 3.5 kg/cm^2. However, the compressed air generation pressure is 6.4 kg/cm^2. In order to reduce pressure drop in the distribution system, most of the visible leaks in the system have been identified and listed in the Appendix - 8/5. After plugging and rectifying the air leaks, it is suggested that the compressor delivery pressure be brought down to 5 or 5.5 kg/cm^2 so that to the extent possible electric power is saved This point needs careful consideration by the plant personnel

E. Compressed Air Leakage

The compressed air distribution system was inspected for leakages. Details of identified leaks are given in Appendix - 8/4

Since the plant is operating continuously round the clock throughout the year, it is difficult to undertake a comprehensive compressed air leakage test. However, whenever the plant is taken for a shut down by maintenance department, it is important to undertake the leak test.

During the study period, a plant shutdown did not take place, and therefore the detailed leak test could not be conducted. However, a joint inspection survey was conducted together with the plant personnel and the maximum number of visible leaks were identified and listed in Appendix - 8/4. For the benefit of the plant personnel the procedure for the comprehensive leak test is explained in detail in Appendix - 8/3

F. Machine Side Observations

(i) Air Suction filters for compressors were observed to be filled with dust. Choked filters need regular and frequent cleaning/replacement. Increased pressure drop across the filter leads to increased power consumption.

(ii) Some of the pressure gauges on the compressors, especially on compressors A, B, C & D are not functioning Faulty gauges need regular replacement for precise monitoring of operating parameters

(iii) The air receivers are presently fitted with automatic drain valves operating on a short duration cycle Depending on the condition of the released air and the amount of moisture, it may be considered to extend the time interval between successive valve openings, thereby conserving air in the air receiver.

G. Application of Flat Belts in Lieu of V-belts in Motor Drives

Flat belt drives are becoming increasingly popular replacing V-belts Besides achieving an energy saving of around 3%, flat belts are easy to maintain and contribute to standardised inventory holding and variety reduction

In the plant, the following equipment have been found suitable for application of flat belts.

A. Air Compressors
B. Air Blower
C Hydrogen Blower
D. Hydrogen compressor

The following tabulation gives a summary of the energy savings which could be achieved Details are given in Appendix - 8/5.

Sl No	Item	Annual Savings	
		kWh/year	Rs./yr
1	Air compressor - A	3154	5424
2	Air compressor - C	3427	5895
3	Air compressor - D	3406	5858
4.	Air blower - B	319	549
5	H_2 blower - A	994	1710
6	H_2 compressor - B	7416	12756
7	H_2 compressor - C	12492	21486
TOTAL		**31208**	**53678**

RECOMMENDATIONS

A. The FAD performance of the air compressors should be improved This measure will yield energy savings to the extent of 153696 kWh/year (Rs 264356/year). The cost of implementation is estimated as Rs.4,00,000 with a simple payback period of 1.5 years.

B. The compressed air leakage survey has identified the visible leaks in the distribution system. The same has been recorded to facilitate rectification

C. The feasibility of applying flat belts in lieu of V-belts was studied. It is beneficial to take up this change BY incorporating flat belts to air compressors, air blowers, hydrogen blowers and hydrogen compressors the energy savings are estimated to be 31208 kWh/year (Rs 53678/year). The cost of implementation is estimated to be Rs 1,20,000 with an average simple payback period of 5.3 years.

8.4 SUMMARY OF POTENTIAL ENERGY SAVINGS

Sl No	Proposal	Energy savings		Cost of implementation Rs	Simple pay back period (Years)
		kWh/yr	Rs./Yr		
1	FAD improvement on air compressor	153696	264356	400000	1 5
2	Application of flat belts in air compressor, air blower, H_2 blower and H_2 compressor	31208	53678	120000	5 3 (Avg)
Total		**184904**	**318034**	**520000**	-

9.0 STEAM GENERATION, DISTRIBUTION & UTILISATION

9.1 FACILITY DESCRIPTION

The plant has one Boiler of rated capacity 2000 kg/hour and a steam generation pressure of 10 5 kg/cm^2. The steam utilisation points in the plant are as below

(I) Cell House 1 - Heating of recycled caustic
(II) Cell House 2 - Heating of brine and recycled caustic
(III) Chlorine Bottling Area - Chlorine bottle drying.

The general specifications of the IAEC boiler are given in Appendix - 9/1 The boiler is provided with a separate chimney.

9.2 Energy Consumption

Annual furnace oil consumption in the boiler for the periods 1993-94, 1994-95, 1995-96 are tabulated below.

Year	Consumption (kL)
1993-94	28 8
1994-95	221 04
1995-96	213 36

Based on an analysis of past data the hourly furnace oil consumption has been worked out at 61 litres/hour at full load and 48 litres/hour at low load.

9.3 OBSERVATIONS, ANALYSIS & FINDINGS

A. Steam Generation Aspects

a. Boiler Efficiency Evaluation

The formulae employed for calculation of various heat losses are given in Appendix - 9/2.

Average values of various parameters observed for efficiency evaluation of the IAEC boiler before and after excess air control are as given below:

Sl No	Particulars	Before Excess Air Control	After Excess Air Control
1	Av.% CO_2	8.5	11 5
2.	Av.flue gas temperature	188^{0}C	190^{0}C

It can be observed that % CO_2 has improved considerably from 8.5% to 11.5% after adjusting the intake of excess air

Calculation details of various heat losses and efficiency of the boiler are given in Appendix - 9/3. Summary of heat losses and efficiency of the boiler with and without excess air control is tabulated below

Sl. No	Particulars	Before excess air control %	After excess air control %
1.	Heat input	100	100
2.	Heat loss as sensible heat	9 8	6.9
3	Heat loss due to hydrogen in fuel	7	6 92
4	Heat loss due to moisture in air	0.18	0 13
5.	Radiation and convection losses	1 0	1.0
6.	Thermal efficiency	82 02	85.05

Efficiency of boiler before and after excess air control works out to approximately 82% and 85% respectively

b. Energy Savings by Excess Air Control

Regular monitoring of exit flue gases (% CO_2 and temperature) goes a long way towards reduction of energy consumption. This can be achieved by regular monitoring (at least once a shift preferable) using a portable gas analyser. Implementation of this measure is expected to result in energy savings to the tune of 12952 litres of furnace oil per year The value of savings amounts to Rs.72531 per year with a simple payback of 0.7 years. Details are given in Appendix - 9/4.

The boiler operation was studied on 11.6.97 and the observed data are given in Appendix - 9/5.

c. Energy Savings by Recovery of Heat in Condensate for Feed Water Heating and Replacing DM Water

Average temperature of steam condensate is 98^{0}C. The quantity of condensate presently being disposed off in the drain is approx. 3950m^3/year. By systematically collecting and transporting the condensate water to the feed water system, the potential feed water temperature will rise and it will replace equivalent quantity of DM water.

Implementing this measure is expected to yield annual DM water savings of 3950 m^3 with a simple payback of 0.8 years. The cost of implementation will be Rs.1,50,000. Details given in Appendix - 9/6.

B. Steam Distribution

a. Steam Leakages

It is observed that steam leakages are present in the pipeline system The leakages are mostly from glands, valves, drain pipes, etc. Sources of leakages and estimated quantities have been tabulated in Appendix - 9/7. Quantified steam leakages work out to approximately 174 8 tons per year. Plugging the steam leakages at a cost of approximately Rs.25,000 will have a simple payback of 0.57 year. Details are given in Appendix - 9/7

b. Insulation Aspects

A survey of the steam distribution network was carried out to identify and quantify the heat losses from uninsulated steam mains, flanges, valves , etc. It is observed that by and large, the extent of insulation provided is adequate. However, there are a few uninsulated valves and flanges which will lead to heat losses. Details of uninsulated items and their locations together with heat loss are given in Appendix - 9/8. Potential energy savings achieved by insulating these items is also given in Appendix - 9/8.

C. *Trapping System*

Steam tramps are provided in the branch lines. A survey of the trapping system reveals malfunctioning of most of the traps. This could be rectified by systematic maintenance. It is advisable to provide strainers before the traps. Details of the steam trap survey is summarised in Appendix - 9/9.

9.4 RECOMMENDATIONS

a. Regular monitoring of exit flue gases should be carried out using a portable gas analyser. The manufacturer of the boiler, viz , IAEC should be contacted and the damper positional control system be rectified at the earliest so that excess air could be controlled smoothly.

Implementation of this measure of improving the % CO_2 is expected to yield energy savings of 12952 litres of furnace oil per year (Rs.72531/year) with a simple pay back period of 0.7 years.

Energy savings	= 12952 litres of FO/yr
Value of savings	= Rs.72,351/ yr
Cost of implementation	= Rs.50,000/-
Simple payback period	= 0 7 years

b. Preheating of feed water by mixing with recycled condensate hot water will save consumption of DM water This measure is expected to yield annual savings of DM water of 3950 m^3 (Rs 197518/year) with a simple payback period of 0 8 years.

DM water savings = 3950 m^3/yr

Value of savings = Rs.197518/ yr

Cost of Implementation = Rs.1,50,000

Simple pay back period = 0 8 years

c. Existing major steam leakages as identified should be plugged at the earliest Annual energy savings to the tune of 174.8 tons of steam (Rs 43,700/year) exists with a simple payback period of 0 57 year.

Energy savings = 174 8 tons of steam/yr

Value of savings = Rs.43,700 /yr

Cost of implementation = Rs 25,000

Simple payback period = 0 57 year

d. Insulation of uninsulated valves, flanges, etc should be taken up. This has potential annual energy savings of 136 tons of steam (Rs 34000/year) with a simple payback period of 0.25 year

Energy savings = 136 tons of steam/year

Value of savings = Rs 34,000/year

Cost of implementation = Rs 8640

Simple pay back period = 0 25 year

9.5 SUMMARY OF POTENTIAL ENERGY SAVINGS

Sl No	Proposal	Annual Savings				Cost of implementation (Rs)	Simple payback period (Years)
		Steam (Tons)	F O (Lts)	DM Water (m^3)	Value of savings (Rs)		
1	Savings by excess air control	-	12952	-	72531	50000	0 7
2	Savings by recovery of condensate and replacing DM water	-	-	3950	197518	150000	0 8
3	Plugging steam leakages	174 8	-	-	43700	25000	0 57
4	Insulation of uninsulated valves and flanges	136	-	-	34000	8640	0 25
	Total	**310.8**	**12952**	**3950**	**347749**	**233640**	

10.0 PUMPS AND BLOWERS

10.1 FACILITY DESCRIPTION

Plant uses pumps and blowers for handling various liquids such as, brine, caustic soda, hytherm oil, cooling water etc , Detailed specification of pumps and blowers indicating design flow and head has been given in Appendix - 10/1

10.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Matching of Drive and Driven Equipment

Based on the design flow and head, connected loads of drives have been observed to be in conformity with the requirement However, in some of the locations higher size drives have been provided to compensate for lower pump efficiency

B Loading Pattern of Pumps.

Section-wise loading pattern of pumps is given in Appendix - 10/1 Majority of the drives have loading falling in the range 70% - 90% Observations on discharge pressure of various pumps in Cell House-I & Cell House-II are given in Appendix - 10/2

C. Energy Savings by Replacing Existing Inefficient Pump by New Efficient Pump

Based on the actual power input and pressure observed, efficiency of thermic fluid heater pump is calculated. The efficiency of the pump is calculated to be 32% Calculation details are given in Appendix - 10/3. Since the efficiency of the pump is low, it is preferable to replace it by new efficient pump. By doing so, the potential annual energy saving is to the tune of Rs. 52,000 with a simple payback period of 2 years. Calculation details are given in Appendix - 10/4.

D ***Energy Savings by Replacing Existing Inefficient Pumps by New Efficient Pumps.***

Totally 11 number of pumps have been identified to be inefficient ones which need to be replaced by new efficient ones in the entire plant. Potential annual energy savings by this measure works out to 1,46,460kWh (i.e. Rs. 2,51,700/-) with a simple payback of 2.5 years Calculation details are given in Appendix - 10/5.

10.3 RECOMMENDATIONS

A The existing inefficient thermic fluid circulation pump in concentration plant should be replaced by new one This measure is expected to result in annual energy saving of Rs 52,000/- with a simple payback of 2 years (Section 10 2-C)

Annual energy savings	=	.30244 kWh
Cost of energy savings	=	Rs 52,000/-
Cost of investment	=	Rs 1,00,000/-
Simple payback period	=	2 years

B 11 number of inefficient pumps identified should be replaced by efficient ones This measure is expected to result in annual energy saving of 146460 kWh (i e Rs 2,51,700/-) with a simple payback of 2 5 years . (Section 10 2-D)

Annual energy savings	=	146460 kWh
Cost of energy savings	=	Rs 2,51,700/-
Cost of investment	=	Rs 6,18,000/-
Simple payback period	=	2 5 years

10.4 SUMMARY OF POTENTIAL SAVINGS

Sl. No	Proposal	Annual Savings		Cost of implementation Rs (lakh)	Simple payback period Years
		Energy kWh	Cost Rs.		
1	Replacement of inefficient thermic fluid pump by new efficient one	30,240	52,000	1,00,000	2
2	Replacement of 11 numbers of inefficient pumps by new efficient ones	1,46,460	2,51,700	6,18,000	2 5
Total		**1,76,700**	**3,03,700**	**7,18,000**	**2.4**

11.1 COOLING TOWERS - MAIN

11.1.1 FACILITY DESCRIPTION

The main cooling tower caters to cooling water requirements of concentration plant, Hydrochloric acid plant, Cell House - I & II. Detailed specifications are given in Appendix - 11/1.

11.1.2 OBSERVATIONS ANALYSES AND FINDINGS

A. Performance Evaluation of Cooling Towers

Towards performance evaluation, the following parameters were monitored

i. Ambient dry and wet bulb temperature
ii. Cooling water inlet and outlet temperatures

From the above measured values, range and approach have been computed for the main cooling tower

The details are given in Appendix - 11/2. The highlights of the above observation are given below.

Range and Approach values:

Range (°C)			
Time	Cell 1	Cell 2	Cell 3
9 00	3.9	4.5	5
10 00	4 5	4.5	5.5
11 45	4	5 0	5.5
13.30	4.5	5 0	5
15 45	4	5.5	5
Avg.	4.18	4.9	5.2

Approach (°C)			
Time	Cell 1	Cell 2	Cell 3
	(°C)	(°C)	(°C)
9.00	2.6	3.0	1 5
10.00	4 0	4.0	2 0
11.45	2.5	2.5	1 0
13.30	2 0	1 5	1 0
15 45	2 0	1.5	1.5
Avg.	2 62	2 5	1.4

It can be observed from the above values that the performance of the cooling tower is satisfactory. The observed approach value of 1 4 °C to 2.62 °C is considered good.

The make up water is calculated to be around 4 876m^3/h or 117 m^3/day Measured average air flow rate at discharge of fans is observed to be 56 m^3/h to 66 m^3/h. Measured dry bulb and wet bulb temperatures at exit of fans is given in Appendix-11/2.

B Assessment of heat Loads of various user areas

The measurement of cooling water flows to various user areas was carried out using ultrasonic flow meter By measuring the temperature rise, heat loads have been computed The total heat load for the cooling tower works out to 23,66,120 kcal/h, which is about 45% of the design load. Summary of heat distribution load is given below·

Cooling water user Area	Heat Load kcal/h	% heat load
Concentrator plant		
Surface condenser	10,48,000	44.3
caustic PHE- I	1,17,000	4.9
Caustic PHE-II	91,000	3.8
Total	12,56,000	53
Hydrochloric acid plant	6,50,000	27
Cell House -II	2,50,425	11
Cell House -I	2,09,695	9

Details are given in Appendix - 11/3.

The measured cooling water flows to various user areas are tabulated in Appendix - 11/4

C. Energy Savings by Replacement with FRP blades

This aspect has been discussed in Chapter 4.0

11.2 LIQCHLOR SECTION COOLING TOWER

11.2.1 FACILITY DESCRIPTION

This cooling tower has the function of cooling the water flowing out from the freon compressor system, air compressors, chilled water machine belonging to the chlorine production and bottling plant.

11.2.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Loading Pattern

Loading pattern of cooling tower pump and fan is tabulated below

Sl No.	Pump	Rated kW	Actual kW	% loading
2	B	18.5	16 83	90.9

Sl. No.	Fan No.	Rated kW	Actual kW	% Loading	PF
1	A	15	7 29	48 6	0 75

It can be observed that the pump is loaded adequately, but the fan is underloaded The PF is also low at 0.75

The fan exit air velocity was measured and the details are tabulated below

Motor frequency C/s	Velocity		
	At centre hub m/s	fan middle m/s	fan edge m/s
50	8.5	4 4	2 0

It is observed that the velocity figures are below the desired normal figure of 12 m/s

B. Performance evaluation of cooling tower

Towards the performance evaluation of the cooling tower, the following parameters were monitored Details of data collected are given in Appendix - 11/5

(a) Ambient Dry and Wet Bulb temperature

(b) Cooling water inlet and outlet temperatures.

From the data collected, the range and approach have been calculated. The summary is tabulated below:

Av. Inlet water temp ^{0}C	Av. Outlet water temp ^{0}C	Approach ^{0}C	Range ^{0}C	Dry bulb temp ^{0}C	Wet bulb temp ^{0}C
32 8	30 4	2 4	2.4	30.5	28

Detailed observations are given in Appendix - 11/5.

The following observations need careful attention.

(a) The cooling tower fan is fitted with super mizer VSD. However, it is operating in manual mode since the temperature sensors are not connected in the circuit. Even with the VSD the fan motor is loaded only upto 48 6 % with 0 75 p.f

(b) The air velocity at the exit side of the fan is low compared to normal standards This results in slow movement of air upwards leading to poor heat extraction by the fan.

(c) The calculated range is 2.4^{0}C and the approach is also 2.4^{0}C. The figure for approach is acceptable, but the figure for range is too narrow. It is generally observed that for efficient cooling towers the range would be at least 5^{0}C.

(d) The focus problem areas in the cooling tower are as follows:

   (i) Motor underloaded and pf low
   (ii) Air velocity low at full speed
   (iii) Range is low

(e) Some of the possible solution approaches to the above problem could be as given below:

(i) Incorporate dynamically balanced FRP fan blades instead of the present metallic fan blades.

(ii) After checking the motor loading at full speed, go in for an appropriate sized motor to optimise and improve motor loading and pf.

(iii) Efforts should be made to improve the range of cooling tower by means of the following:

   (a) Improve the surroundings of the cooling tower in order to avoid obstacles for air movement, so that air could be sucked and induced through the louvres and the water film.
   (b) Also improve the blade angles, of the fan so that air flow is increased. The cooling tower supplied should be contacted to find out the details of the improved blade angles and inclination
   (c) The rate of discharge of hot water into the cooling tower and the spread of the water film should be appropriately changed after discussion with the cooling tower supplier to improve the cooling range
   (d) The make up water requirement is evaluated for the cooling tower Details are given in Appendix - 11/6 The make up requirement works out to 0 91 m^3/h
   (e) The heat load on the cooling tower is calculated and is 4,41,600 kcal/h. Details are given in Appendix - 11/8.

12.0 LIGHTING SYSTEM

Total plant lighting system study was carried out. This study covers measurement of lighting load, voltage condition, lux levels in the factory areas etc

12.1 FACILITY DESCRIPTION

The plant total connected lighting load is about 40 kW. The plant makes extensive use of HPSV, HPMV and fluorescent fixtures in different areas.

The total plant lighting load is distributed through main lighting distribution board located at HT room The incomer to MCDB is fed from PCC and an alternative source is provided from DG set through change over arrangement There are no lighting transformers earmarked for this purpose leaving no scope of controlling the lighting circuit voltage at present.

The lighting loads to different sectors is distributed through separate MCB from the main lighting DB as listed below .

* Street lighting
* Executive office MCB
* MCCI & QC Lab MCB
* Cell house # 2 MCB
* Boiler House MCB
* 110 kV Switchyard MCB
* HT room MCB
* Rectifier room 2 MCB
* Rectifier room 1 MCB
* MCC5 & Liqchlor MCB

12.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. GENERAL

1. Plant management has initiated practice of controlled switching manually in all the areas of lighting and is duly followed.

2. Plant management has provided at selected locations HPSV lamps for energy efficiency.

3. In hydrogen bottling area specially protected ML lamps are being used for safety reasons

4 Lighting levels in process areas of cell house # 1 and cell house # 2 needs to be improved. Relocation of the present HPSV/HPMV used at the process plat forms is to be accordingly done for better illumination.

Plant management has initiated and provided better methods of switching operation of lighting. Day to day energy consumption on lighting load is monitored through a separate independent kWh meter

B. Lighting Load Parameters

Power measurement has been carried out on various MCB to assess the system lighting load. This is found to be 30 5 kW The details of measurements are indicated in Appendix - 12/1

The voltage level is observed to be at higher level between 226 to 232 volts and the pf is observed to be between 0 63 - 0.9 lag

C. Illumination Levels

The lux levels were measured at various locations of the plant and are presented in Appendix - 12/2 Generally the level of illumination conform to the guide line prescribed in IS 3646. However, in some areas the lighting level requires improvement by way of strengthening, re-distributing fixtures.

D. Energy Efficient Lighting

I. By use of reduced voltage (to the tune of 210 - 215 volts) exclusively for lighting circuit, a saving of 10-15% lighting energy consumption can be achieved

The reduced voltage of the above mentioned level does not impair the ability of discharge lamps to strike and no significant reduction in lumen output is noticed Besides use of higher voltage tend to reduce the life of luminaires. The detailed study is presented in Appendix - 12/3.

II During our discussion with plant maintenance officials, it is gathered that experience related to use of electronic choke have not been satisfactory Yet due to improved manufacturing process and standardisation adopted by manufacturers, reliable source of supply is currently available Use of electronic choke can help in annual energy saving to the tune of 9373 kWh with simple payback period of 3.98 years (Appendix - 12/4).

12.3 RECOMMENDATIONS

A. GENERAL

1 Periodic cleaning of luminaires should be carried out to get maximum lumens per watt consumed. Plant personnel are already carrying out this activity periodically.

2 One fluorescent tube of 2 x 40 W twin fluorescent tube is already removed by plant personnel for energy savings. But the choke is in circuit consuming around 4 - 6 watt. All such chokes can be disconnected from circuit.

B. Energy Efficient Lighting

I. Use of reduced voltage through exclusive lighting transformer deployed shall yield following savings. (Appendix - 12/3).

Annual energy savings	= 13359 kWh
Cost of annual energy savings	= Rs 22,978/-
Cost of implementation	= Rs 85,000/-
Simple payback period	= 3.7 years

II Use of electronic chokes for fluorescent tube fixtures shall yield following savings. (Appendix - 12/3)

Annual energy savings	= 9373 kWh
Cost of annual energy savings	= Rs 16121/-
Cost of implementation	= Rs 64,200/-
Simple payback period	= 3 98 years

12.4 SUMMARY OF POTENTIAL SAVINGS

Sl No	Recommendations	Annual energy savings		Investment required	Simple Payback period
		kWh	Rs	Rs	Years
1.	Energy saving by voltage controller	13359	22978	85000	3 7
2	Installation of electronic chokes for fluorescent tubes	9373	16121	64200	4 0
	Total	**22732**	**39099**	**149200**	**3.8**

13.0 CONCLUSION

The scope for conservation of energy at Chemfab alkalis Ltd. has been studied and discussed in detail. There appears to be a good scope for reducing the energy consumption by implementation of various energy conservation opportunities discussed before.

The implementation of these recommendations calls for active involvement and co-operation from all departments.

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APPENDICES

APPENDIX - 2/1

SPECIFIC POWER AND FURNACE OIL CONSUMPTION

Month/ Year	Electrolysis kWh/Mt	Auxiliaries kWh/Mt	Total kWh/Mt	FO lit/t
Apr'96	2404	391	2840	96.8
May	2426	370	2831	70.38
Jun	2470	341	2857	45.73
Jul	2506	327	2867	31.47
Aug	2511	323	2870	14.00
Sep	2508	343	2895	40.42
Oct	2523	347	2921	20.23
Nov	2546	320	2909	27.72
Dec	2516	341	2900	46.66
Jan'97	2497	332	2876	35.58
Feb	2423	434	2901	53.58
Mar	2440	403	2887	47.38

110 kV MAIN SYSTEM POWER MEASUREMENT DETAILS FOR A TYPICAL DAY

DATE : 13th,June '97

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos φ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
14.30	100.0	27.4	48.1	57.6	58.0	57.7	27.9	27.4	27.9	4740	4750	246	1.00	1590	1570	1590	500	100	2770	2750
14.34	100.0	27.7	48.1	57.7	58.2	58.0	27.9	27.4	27.9	4750	4820	800	0.99	1590	1570	1600	800	100	2770	2750
14.41	99.5	27.2	48.0	57.2	57.7	57.4	27.7	27.2	27.5	4680	4690	185	1.00	1570	1550	1570	1300	100	2770	2750
14.45	99.2	27.0	48.0	57.0	57.5	57.3	27.5	26.9	27.3	4630	4640	810	1.00	1550	1530	1550	1600	100	2770	2750
14.49	99.2	27.4	48.0	57.0	57.5	57.3	27.9	27.2	27.7	4690	4700	840	1.00	1570	1550	1570	1900	100	3720	3700
14.56	99.1	27.3	48.0	57.0	57.4	57.2	27.8	27.2	27.7	4690	4690	822	1.00	1570	1550	1570	2400	100	4690	4670
15.00	100.0	28.1	48.0	57.5	57.9	57.8	28.5	27.7	28.3	4820	4870	753	0.99	1620	1590	1610	2700	200	4820	4800
15.04	101.0	28.3	48.0	57.8	58.3	58.1	28.6	27.8	28.5	4860	4920	792	0.99	1630	1600	1630	3000	200	4820	4800
15.11	101.0	27.3	48.1	57.7	58.2	58.1	27.5	26.9	27.4	4680	4750	785	0.99	1570	1540	1570	3600	300	4830	4820
15.15	101.0	27.4	48.0	57.8	58.2	58.0	27.6	27.0	27.6	4710	4770	756	0.99	1580	1550	1590	3900	300	4850	4840
15.19	101.0	27.5	48.0	57.8	58.2	58.0	27.8	27.2	27.7	4720	4790	844	0.98	1580	1560	1580	4200	400	4870	4850
15.26	101.0	27.3	48.0	57.9	58.3	58.1	27.6	26.9	27.5	4680	4760	857	0.98	1570	1540	1580	4800	500	4880	4850
15.30	100.0	27.4	47.9	57.6	58.1	57.8	27.6	27.0	27.5	4680	4750	791	0.99	1570	1540	1570	5100	500	4890	4850
15.34	99.5	27.4	47.9	57.2	57.7	57.4	27.7	27.1	27.6	4670	4730	732	0.99	1560	1540	1570	5400	600	4890	4850
15.41	99.7	27.4	47.8	57.3	57.7	57.6	27.6	27.0	27.6	4670	4730	763	0.99	1560	1540	1570	6000	700	4890	4850
15.45	99.9	27.3	47.9	57.5	57.9	57.7	27.5	26.9	27.5	4660	4730	780	0.99	1560	1540	1570	6300	700	4890	4850
15.52	99.4	27.5	47.9	57.1	57.6	57.4	27.7	27.1	27.6	4670	4730	720	0.99	1560	1540	1570	6700	800	4890	4850
15.56	99.2	27.5	48.0	57.0	57.4	57.3	27.7	27.1	27.6	4660	4720	743	0.99	1560	1540	1560	7100	900	4890	4850
16.00	99.9	27.1	48.0	57.4	57.9	57.7	27.6	27.0	27.6	4670	4680	280	1.00	1560	1540	1570	7400	900	4890	4850
16.04	100.0	27.6	48.2	57.8	58.2	57.9	27.9	27.3	27.7	4730	4800	818	0.99	1590	1560	1580	7800	1000	4890	4850
16.11	101.0	27.5	48.1	58.3	58.8	58.6	27.8	27.1	27.8	4750	4830	911	0.98	1590	1560	1600	8300	1100	4890	4850
16.15	101.0	27.7	48.1	58.0	58.5	58.2	28.0	27.3	27.8	4740	4840	958	0.98	1590	1560	1590	8600	1100	4890	4850
16.19	101.0	28.5	48.2	57.8	58.2	58.0	28.8	28.1	28.6	4860	4960	961	0.98	1630	1600	1630	8900	1200	4890	4850
16.26	101.0	28.9	48.1	57.8	58.2	58.0	29.2	28.7	29.0	4940	5040	978	0.98	1660	1640	1650	9500	1300	4890	4850
16.30	99.5	28.9	48.1	57.2	57.7	57.4	29.1	28.5	29.1	4900	4980	393	0.98	1640	1620	1640	9900	1400	4920	4870
16.34	99.9	28.9	48.1	57.5	57.9	57.7	29.1	28.6	29.0	4930	5000	879	0.98	1650	1630	1650	10200	1400	4920	4870
16.41	99.4	29.3	48.1	57.2	57.6	57.4	29.6	29.0	29.4	4980	5050	848	0.99	1670	1640	1660	10800	1500	4950	4890
16.45	99.7	29.5	48.2	57.4	57.8	57.6	29.7	29.1	29.6	5010	5090	879	0.99	1680	1660	1680	11200	1600	4970	4920

Appendix - 3/1 Contd.

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos φ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
16.52	101.0	30.0	48.5	57.8	58.2	58.0	30.2	29.6	30.1	5140	5220	863	0.99	1720	1700	1730	12600	1800	5030	4990
16.56	99.7	30.1	48.6	57.4	57.8	57.6	30.3	29.7	30.2	5130	5200	849	0.99	1710	1690	1720	12800	1900	5030	4990
17.00	99.7	30.6	48.8	57.3	57.8	57.6	30.9	30.3	30.6	5220	5280	818	0.99	1750	1730	1740	13300	1900	5050	5010
17.04	99.8	32.4	48.7	57.4	57.8	57.6	32.7	32.1	32.5	5530	5600	822	0.99	1850	1830	1850	13600	2000	5080	5040
17.11	99.3	35.8	48.6	57.1	57.6	57.3	36.0	35.6	35.8	6070	6160	1020	0.99	2030	2010	2030	14100	2100	5210	5170
17.15	98.3	38.5	48.5	56.5	57.0	56.8	38.7	38.3	38.6	6460	6560	1150	0.99	2150	2150	2160	14800	2200	5410	5370
17.19	97.9	38.8	48.5	56.3	56.8	56.6	38.9	38.6	38.8	6480	6570	1100	0.99	2160	2150	2170	15200	2300	5750	5670
17.26	97.9	39.9	48.4	56.3	56.8	56.6	40.0	39.7	39.9	6650	6760	1200	0.98	2220	2220	2220	15700	2400	5750	5670
17.30	98.2	38.8	48.3	56.5	56.9	56.7	38.8	38.7	38.8	6510	6600	1070	0.99	2170	2170	2170	16500	2500	6090	6010
17.34	97.8	38.7	48.3	56.2	56.6	56.5	38.8	38.6	38.7	6470	6550	1040	0.99	2160	2150	2160	16900	2600	6430	6340
17.41	97.5	38.4	48.2	56.0	56.5	56.3	38.6	38.4	38.4	6410	6490	1010	0.99	2140	2140	2130	17400	2600	6650	6460
17.45	97.9	38.6	48.4	56.3	56.7	56.5	38.7	38.5	38.6	6460	6540	1050	0.99	2150	2150	2150	18000	2700	6800	6500
17.52	98.6	39.1	48.5	56.7	57.1	56.9	39.2	39.0	39.1	6580	6680	1130	0.99	2200	2190	2190	18400	2800	6800	6500
17.56	99.0	38.8	48.6	57.0	57.4	57.1	39.0	38.7	38.7	6570	6650	1050	0.99	2190	2190	2190	18900	2900	6800	6500
18.00	99.9	38.9	48.8	57.4	57.9	57.7	39.1	38.8	38.9	6640	6740	1130	0.99	2210	2210	2220	19700	3000	6800	6500
18.04	99.4	38.9	48.6	57.2	57.6	57.4	39.0	38.8	38.9	6600	6700	1130	0.99	2200	2200	2200	20100	3100	6800	6500
18.11	98.9	39.0	48.5	56.9	57.3	57.1	39.1	38.8	39.0	6580	6670	1120	0.99	2190	2190	2190	20500	3200	6810	6600
18.15	98.1	38.6	48.2	56.4	56.8	56.7	38.7	38.5	38.5	6470	6560	1060	0.99	2160	2160	2160	21300	3300	6830	6710
18.19	98.0	38.6	48.1	56.4	56.8	56.6	38.6	38.4	38.6	6460	6550	1080	0.99	2150	2150	2160	21700	3400	6830	6710
18.26	98.2	38.7	48.3	56.5	56.9	56.7	38.9	38.6	38.7	6490	6590	1120	0.99	2160	2160	2170	22200	3400	6840	6710
18.30	98.5	38.7	48.3	56.6	57.1	56.9	38.8	38.7	38.7	6510	6610	1130	0.99	2170	2170	2170	23000	3600	6840	6710
18.34	98.2	38.8	48.2	56.5	56.9	56.7	38.9	38.7	38.8	6500	6600	1140	0.99	2170	2170	2170	23500	3700	6840	6710
18.41	98.4	38.8	48.2	56.6	57.0	56.8	38.9	38.7	38.7	6510	6610	1110	0.99	2170	2170	2170	23900	3700	6840	6710
18.45	97.6	38.7	47.9	56.1	56.5	56.4	38.9	38.7	38.7	6470	6550	1040	0.99	2160	2150	2160	24500	3800	6840	6710
18.52	97.7	38.9	48.1	56.2	56.6	56.4	39.0	38.8	38.9	6490	6580	1080	0.99	2160	2160	2170	25000	3900	6840	6710
18.56	97.9	38.9	48.1	56.3	56.7	56.5	39.1	38.8	38.9	6510	6600	1090	0.99	2170	2170	2170	25400	4000	6840	6710
19.00	97.9	38.9	48.1	56.3	56.7	56.6	39.0	38.8	38.9	6510	6590	1070	0.99	2170	2170	2170	26200	4100	6840	6710
19.04	97.5	38.7	47.9	56.1	56.4	56.4	38.9	38.6	38.7	6460	6540	1040	0.99	2150	2150	2150	26600	4200	6840	6710
19.11	97.6	38.9	48.0	56.1	56.5	56.4	39.0	38.8	38.8	6490	6570	1070	0.99	2160	2160	2160	27000	4300	6840	6710
19.15	97.6	39.0	47.8	56.1	56.6	56.4	39.1	38.9	38.9	6500	6590	1090	0.99	2160	2170	2170	27800	4400	6840	6710
19.19	98.0	38.9	47.9	56.3	56.8	56.6	39.0	38.9	38.9	6510	6600	1130	0.99	2170	2170	2170	28200	4500	6840	6710

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos φ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
19.26	98.2	39.2	47.9	56.4	56.9	56.7	39.3	39.1	39.2	6550	6660	1180	0.98	2180	2180	2190	28700	4500	6840	6710
19.30	98.3	38.8	47.8	56.5	57.0	56.8	39.1	38.6	38.8	6530	6610	1020	0.99	2180	2170	2180	29500	4700	6840	6710
19.34	98.4	38.8	48.1	56.6	57.0	56.9	39.0	38.7	38.8	6540	6620	1050	0.99	2180	2180	2180	30000	4800	6840	6710
19.41	99.2	39.1	48.1	57.0	57.5	57.3	39.2	38.9	39.1	6610	6710	1160	0.99	2200	2200	2210	30400	4800	6840	6760
19.45	98.7	38.5	47.9	56.7	57.2	57.0	38.6	38.4	38.5	6470	6570	1150	0.99	2160	2160	2160	31100	4900	6840	6760
19.52	98.1	38.4	48.0	56.4	56.9	56.7	38.6	38.2	38.5	6450	6530	1040	0.99	2150	2140	2160	31500	5000	6840	6760
19.56	98.7	38.8	47.9	56.7	57.2	57.0	38.9	38.7	38.8	6540	6630	1110	0.99	2180	2180	2180	31900	5100	6840	6760
20.00	98.3	38.5	48.0	56.5	57.0	56.8	38.6	38.3	38.5	6470	6550	1010	0.99	2160	2150	2160	32700	5200	6840	6760
20.04	98.6	38.7	47.8	56.7	57.2	57.0	38.9	38.6	38.7	6520	6610	1070	0.99	2170	2170	2180	33100	5300	6840	6760
20.11	99.1	38.6	47.9	57.0	57.5	57.3	38.7	38.6	38.6	6530	6630	1200	0.98	2170	2180	2180	33600	5400	6840	6760
20.15	100.0	38.4	47.9	57.6	58.0	57.8	38.5	38.3	38.5	6520	6660	1360	0.98	2170	2170	2180	34300	5500	6840	6760
20.19	101.0	38.0	48.1	57.8	58.2	58.1	38.0	37.9	38.0	6510	6610	1140	0.99	2160	2170	2180	34800	5600	6840	6760
20.26	101.0	37.6	48.1	58.0	58.4	58.2	37.8	37.4	37.7	6490	6570	1020	0.99	2170	2160	2170	35200	5700	6840	6760
20.30	101.0	37.7	47.9	57.9	58.3	58.1	37.9	37.5	37.7	6490	6570	1030	0.99	2170	2160	2170	36000	5800	6840	6760
20.34	101.0	37.6	48.0	57.9	58.3	58.1	37.8	37.4	37.6	6470	6560	1030	0.99	2160	2150	2160	36500	5900	6840	6760
20.41	101.0	37.7	48.0	58.1	58.6	58.4	37.9	37.6	37.8	6510	6610	1100	0.99	2170	2170	2180	36900	5900	6840	6760
20.45	101.0	37.7	48.0	58.1	58.5	58.3	37.9	37.5	37.7	6500	6590	1080	0.99	2170	2160	2170	37600	6100	6840	6760
20.52	101.0	37.6	48.0	58.1	58.5	58.3	37.8	37.4	37.7	6490	6580	1090	0.99	2160	2160	2170	38000	6100	6840	6760
20.56	101.0	37.5	48.0	57.8	58.4	58.1	37.6	37.2	37.5	6440	6530	1040	0.99	2150	2140	2150	38400	6200	6840	6760
21.00	101.0	37.5	48.1	57.8	58.3	58.1	37.7	37.3	37.6	6460	6530	943	0.99	2160	2150	2160	39200	6300	6840	6760
21.04	101.0	37.5	48.1	57.9	58.4	58.2	37.7	37.4	37.6	6470	6550	1010	0.99	2160	2150	2160	39600	6400	6840	6760
21.11	101.0	37.6	48.2	58.0	58.4	58.3	37.7	37.4	37.5	6480	6560	1020	0.99	2160	2160	2160	40100	6400	6840	6760
21.15	102.0	37.6	48.2	58.4	58.8	58.6	37.8	37.5	37.6	6520	6610	1120	0.99	2170	2170	2170	40800	6600	6840	6760
21.19	101.0	37.5	48.2	58.1	58.6	58.4	37.6	37.5	37.5	6480	6570	1110	0.99	2160	2160	2160	41300	6600	6840	6760
21.26	101.0	37.5	48.2	58.2	58.6	58.4	37.7	37.4	37.4	6470	6570	1110	0.99	2160	2160	2160	41700	6700	6840	6760
21.30	101.0	37.4	48.2	57.9	58.4	58.2	37.6	37.2	37.4	6440	6530	1020	0.99	2150	2140	2150	42500	6800	6840	6760
21.34	101.0	37.5	48.2	58.1	58.5	58.3	37.7	37.4	37.4	6470	6560	1050	0.99	2160	2160	2160	43000	6900	6840	6760
21.41	101.0	37.2	48.3	58.3	58.7	58.5	37.4	37.1	37.2	6450	6540	1080	0.99	2150	2150	2150	43400	7000	6840	6760
21.45	102.0	37.3	48.4	58.5	58.9	58.7	37.4	37.2	37.2	6470	6560	1100	0.99	2160	2160	2160	44000	7100	6840	6760
21.52	102.0	37.5	48.5	58.9	59.4	59.1	37.6	37.4	37.4	6550	6650	1170	0.98	2180	2190	2180	44500	7200	6840	6760
21.56	103.0	37.8	48.8	59.2	59.7	59.5	37.9	37.7	37.8	6630	6740	1220	0.98	2210	2210	2210	44900	7300	6840	6760

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
22.00	102.0	37.4	48.2	58.5	59.0	58.8	37.5	37.3	37.4	6490	6600	1180	0.98	2160	2160	2170	45700	7400	6840	6760
22.04	102.0	37.4	48.2	58.6	59.0	58.8	37.6	37.4	37.4	6500	6610	1200	0.98	2170	2170	2160	46100	7500	6840	6760
22.11	102.0	37.6	48.1	58.6	59.1	58.8	37.7	37.4	37.6	6520	6630	1230	0.98	2170	2170	2170	46600	7600	6840	6760
22.15	102.0	37.7	48.2	58.7	59.2	58.9	37.7	37.6	37.7	6550	6660	1220	0.98	2180	2180	2190	47300	7700	6840	6760
22.19	102.0	37.5	48.3	58.8	59.3	59.0	37.6	37.4	37.5	6520	6630	1240	0.98	2170	2180	2170	47800	7800	6840	6760
22.26	102.0	37.7	48.1	58.6	59.1	58.8	37.8	37.5	37.8	6550	6650	1160	0.99	2180	2180	2190	48200	7900	6840	6760
22.30	103.0	37.8	48.2	59.0	59.4	59.2	37.9	37.7	37.7	6590	6710	1260	0.98	2200	2200	2200	49100	8000	6840	6760
22.34	102.0	37.5	48.3	58.8	59.3	59.1	37.6	37.5	37.6	6530	6650	1240	0.98	2180	2180	2180	49500	8100	6840	6760
22.41	102.0	37.2	48.1	58.7	59.2	59.0	37.4	37.1	37.3	6510	6590	1020	0.99	2170	2160	2180	49900	8200	6840	6760
22.45	102.0	37.2	48.1	58.9	59.3	59.1	37.3	37.0	37.3	6510	6590	1070	0.99	2170	2160	2170	50600	8300	6840	6770
22.52	103.0	37.2	48.2	59.0	59.5	59.3	37.5	37.2	37.2	6540	6620	1080	0.99	2180	2180	2180	51000	8400	6840	6770
22.56	103.0	37.1	48.1	59.0	59.5	59.3	37.3	37.0	37.1	6510	6600	1080	0.99	2170	2170	2170	51500	8400	6840	6770
23.00	103.0	36.9	48.2	59.2	59.7	59.4	37.0	36.8	37.0	6480	6580	1150	0.99	2160	2160	2160	52200	8600	6840	6770
23.04	103.0	36.8	48.0	59.1	59.5	59.3	36.9	36.6	36.9	6460	6550	1080	0.99	2160	2150	2160	52700	8600	6840	6770
23.11	103.0	37.0	48.0	58.9	59.4	59.2	37.1	36.8	37.1	6480	6560	1010	0.99	2160	2150	2170	53100	8700	6840	6770
23.15	103.0	37.0	48.2	59.3	59.7	59.6	37.1	36.9	37.0	6510	6610	1130	0.99	2170	2170	2170	53800	8800	6840	6770
23.19	103.0	37.2	48.3	59.4	59.9	59.6	37.3	37.1	37.2	6540	6650	1180	0.98	2180	2180	2180	54300	8900	6840	6770
23.26	103.0	36.8	48.3	59.3	59.9	59.6	36.9	36.8	36.8	6480	6580	1140	0.99	2160	2170	2160	54700	9000	6840	6770
23.30	103.0	36.6	48.3	59.4	59.8	59.6	36.7	36.5	36.6	6460	6540	1030	0.99	2150	2150	2160	55600	9100	6840	6770
23.34	104.0	37.0	48.4	59.5	60.0	59.7	37.1	36.9	37.0	6540	6630	1060	0.99	2180	2180	2180	56000	9200	6840	6770
23.41	104.0	37.0	48.5	59.6	60.1	59.8	37.1	36.9	37.0	6560	6640	1040	0.99	2190	2190	2190	56400	9300	6840	6770
23.45	104.0	37.1	48.5	59.7	60.2	59.9	37.1	37.0	37.1	6580	6660	1050	0.99	2190	2190	2200	57100	9400	6840	6770
23.52	105.0	36.6	48.6	60.4	60.8	60.6	36.8	36.4	36.6	6590	6650	906	0.99	2200	2190	2200	57600	9500	6840	6770
23.56	105.0	36.5	48.7	60.3	60.8	60.5	36.8	36.3	36.4	6580	6630	796	0.99	2200	2190	2190	58000	9500	6840	6770

TATA ENERGY RESEARCH INSTITUTE
BANGALORE

DATE : 14th,June '97

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
00.00	104.0	35.9	48.8	60.0	60.4	60.2	36.3	35.7	35.9	6450	6490	692	0.99	2160	2140	2150	58800	9600	6840	6770
00.04	104.0	36.3	48.9	59.9	60.4	60.2	36.4	36.2	36.2	6500	6540	771	0.99	2170	2170	2160	59200	9600	6840	6770
00.11	104.0	36.5	49.0	60.0	60.5	60.2	36.6	36.4	36.4	6540	6590	786	0.99	2180	2180	2180	59600	9700	6840	6770
00.15	105.0	36.7	49.3	60.2	60.7	60.5	36.8	36.6	36.6	6600	6650	741	0.99	2200	2200	2200	60400	9800	6840	6770
00.19	105.0	36.7	49.4	60.4	60.9	60.7	36.9	36.7	36.7	6640	6690	763	0.99	2210	2210	2220	60800	9800	6840	6770
00.26	105.0	36.7	49.6	60.4	60.8	60.6	36.9	36.7	36.7	6640	6680	752	0.99	2210	2210	2210	61300	9900	6840	6770
00.30	105.0	36.8	49.7	60.3	60.8	60.6	36.9	36.7	36.8	6640	6680	782	0.99	2210	2210	2210	62100	10000	6840	6770
00.34	106.0	37.0	49.8	60.8	61.2	61.0	37.1	37.0	37.1	6730	6780	828	0.99	2240	2250	2240	62600	10000	6840	6790
00.41	105.0	36.6	49.9	60.6	61.1	60.9	36.6	36.5	36.6	6620	6670	848	0.99	2200	2210	2210	63000	10100	6840	6820
00.45	106.0	36.4	50.1	60.8	61.3	61.2	36.5	36.3	36.4	6620	6670	808	0.99	2200	2210	2210	63700	10200	6840	6820
00.52	106.0	35.9	50.1	60.9	61.3	61.1	35.9	35.7	35.9	6530	6570	714	0.99	2170	2170	2180	64100	10200	6840	6820
00.56	106.0	35.8	50.2	60.7	61.1	60.9	35.8	35.7	35.8	6490	6530	736	0.99	2160	2160	2170	64600	10300	6840	6820
01.00	106.0	36.1	50.3	60.8	61.2	61.0	36.2	36.1	36.1	6570	6610	736	0.99	2190	2190	2190	65300	10400	6840	6820
01.04	105.0	36.0	50.4	60.6	61.0	60.8	36.1	36.0	36.0	6540	6570	645	1.00	2180	2180	2180	65800	10400	6840	6820
01.11	105.0	36.1	50.5	60.6	61.0	60.8	36.2	36.0	36.1	6550	6580	699	0.99	2180	2180	2180	66200	10500	6840	6820
01.15	106.0	35.6	50.5	60.8	61.3	61.1	35.6	35.6	35.6	6480	6520	759	0.99	2150	2170	2160	67000	10500	6840	6820
01.19	106.0	35.8	50.5	60.7	61.2	61.0	35.8	35.7	35.8	6500	6540	730	0.99	2160	2170	2170	67400	10600	6840	6820
01.26	105.0	35.9	50.5	60.6	61.1	60.9	35.9	35.8	35.9	6510	6550	720	0.99	2170	2170	2170	67900	10600	6840	6820
01.30	106.0	35.9	50.2	60.8	61.2	61.1	35.9	35.9	35.9	6530	6570	721	0.99	2170	2180	2180	68700	10700	6840	6820
01.34	106.0	36.0	50.2	60.8	61.2	61.1	36.1	36.0	36.0	6550	6600	775	0.99	2180	2190	2190	69100	10800	6840	6820
01.41	106.0	35.8	50.4	60.9	61.4	61.2	35.9	35.8	35.9	6530	6580	760	0.99	2170	2180	2180	69600	10800	6840	6820
01.45	106.0	35.9	50.5	60.8	61.3	61.1	36.0	35.9	35.9	6550	6580	676	1.00	2180	2180	2190	70200	10900	6840	6820
01.52	106.0	36.0	50.5	60.7	61.3	61.0	36.1	36.0	36.0	6550	6600	794	0.99	2180	2190	2180	70700	11000	6840	6820
01.56	106.0	36.0	50.4	60.7	61.3	61.1	36.1	36.0	36.0	6550	6590	724	0.99	2180	2190	2190	71100	11000	6840	6820
02.00	106.0	35.5	50.4	61.0	61.6	61.3	35.6	35.4	35.4	6480	6520	693	0.99	2160	2160	2160	71900	11100	6840	6820
02.04	106.0	35.5	50.5	60.9	61.4	61.2	35.6	35.3	35.5	6480	6510	616	1.00	2160	2160	2160	72300	11100	6840	6820
02.11	106.0	35.4	50.5	60.8	61.3	61.1	35.5	35.2	35.3	6450	6480	566	1.00	2150	2150	2150	72700	11200	6840	6820
02.15	106.0	35.4	50.5	60.9	61.4	61.2	35.5	35.2	35.4	6460	6490	623	1.00	2150	2150	2160	73500	11200	6840	6820
02.19	106.0	35.4	50.5	60.8	61.3	61.1	35.5	35.2	35.4	6450	6480	581	1.00	2150	2150	2150	73900	11300	6840	6820
02.26	106.0	34.3	50.5	61.0	61.4	61.3	34.6	34.2	34.3	6290	6310	485	1.00	2100	2090	2100	74400	11300	6840	6820

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
02.30	106.0	36.0	50.4	61.1	61.6	61.5	36.0	36.0	36.1	6580	6630	876	0.99	2180	2200	2200	75200	11400	6840	6820
02.34	106.0	36.1	50.4	61.1	61.6	61.4	36.1	36.1	36.2	6590	6640	867	0.99	2190	2200	2200	75600	11500	6840	6820
02.41	106.0	36.0	50.5	60.9	61.5	61.3	36.0	36.0	36.0	6570	6610	800	0.99	2180	2190	2190	76100	11500	6840	6820
02.45	106.0	36.0	50.5	60.9	61.4	61.2	36.0	36.0	36.1	6560	6610	834	0.99	2180	2190	2190	76700	11600	6840	6820
02.52	106.0	36.0	50.5	60.8	61.3	61.1	36.0	35.9	36.0	6540	6590	824	0.99	2170	2180	2180	77200	11700	6840	6820
02.56	106.0	36.0	50.5	61.0	61.5	61.3	36.0	35.9	36.0	6550	6610	881	0.99	2180	2190	2190	77600	11700	6840	6820
03.00	106.0	36.4	50.5	61.1	61.6	61.4	36.4	36.3	36.4	6640	6700	870	0.99	2210	2220	2220	78400	11800	6840	6820
03.04	106.0	36.1	50.5	60.9	61.3	61.1	36.2	36.0	36.1	6570	6620	828	0.99	2190	2190	2190	78800	11900	6840	6820
03.11	106.0	35.8	50.4	60.7	61.2	61.0	35.8	35.8	35.9	6510	6550	796	0.99	2160	2170	2170	79300	11900	6840	6820
03.15	105.0	36.0	50.5	60.5	61.0	60.7	36.1	35.9	36.0	6510	6560	761	0.99	2170	2170	2170	80000	12000	6840	6820
03.19	105.0	36.0	50.6	60.5	61.1	60.9	36.1	36.0	36.0	6530	6570	756	0.99	2170	2180	2180	80500	12100	6840	6820
03.26	106.0	36.1	50.5	60.7	61.2	60.9	36.2	36.1	36.1	6550	6600	800	0.99	2180	2190	2180	80900	12100	6840	6820
03.30	106.0	36.2	50.6	60.9	61.4	61.2	36.3	36.2	36.2	6600	6650	805	0.99	2190	2200	2200	81800	12200	6840	6820
03.34	106.0	36.1	50.5	60.8	61.3	61.1	36.1	36.0	36.1	6560	6610	818	0.99	2180	2190	2190	82200	12300	6840	6820
03.41	106.0	36.1	50.5	60.8	61.3	61.1	36.1	36.0	36.1	6560	6610	811	0.99	2180	2190	2190	82600	12300	6840	6820
03.45	105.0	36.0	50.5	60.5	61.0	60.8	36.2	35.9	36.1	6530	6570	751	0.99	2170	2180	2180	83300	12400	6840	6820
03.52	106.0	36.1	50.4	60.6	61.1	61.0	36.2	36.0	36.1	6540	6590	768	0.99	2180	2180	2190	83700	12500	6840	6820
03.56	105.0	35.7	50.4	60.4	60.9	60.8	35.8	35.6	35.7	6470	6500	682	1.00	2150	2160	2160	84200	12500	6840	6820
04.00	105.0	36.3	50.4	60.4	60.9	60.7	36.3	36.3	36.3	6550	8600	843	0.99	2170	2190	2190	84900	12600	6840	6820
04.04	105.0	35.8	50.5	60.3	60.9	60.7	35.7	35.9	35.9	6450	6510	916	0.99	2130	2160	2160	85400	12700	6840	6820
04.11	105.0	35.7	50.5	60.6	61.1	60.9	35.9	35.7	35.7	6480	6520	738	0.99	2160	2160	2160	85800	12700	6840	6820
04.15	106.0	35.8	50.4	60.8	61.2	61.0	35.8	35.7	35.8	6500	6550	807	0.99	2160	2170	2170	86600	12800	6840	6820
04.19	106.0	35.7	50.4	60.7	61.1	61.0	35.8	35.5	35.7	6480	6520	748	0.99	2160	2160	2170	87000	12900	6840	6820
04.26	105.0	35.5	50.3	60.5	60.9	60.7	35.6	35.3	35.5	6410	6450	754	0.99	2140	2130	2140	87400	12900	6840	6820
04.30	105.0	35.8	50.0	60.4	60.9	60.7	36.0	35.6	35.8	6480	6510	649	1.00	2170	2150	2160	88300	13000	6840	6820
04.34	105.0	35.8	50.0	60.4	60.9	60.7	36.0	35.6	35.8	6480	6510	649	1.00	2170	2150	2160	88300	13000	6840	6820
04.41	105.0	35.8	49.8	60.4	60.9	60.7	36.0	35.5	35.7	6470	6510	692	0.99	2160	2150	2160	88700	13100	6840	6820
04.45	105.0	35.6	49.8	60.4	60.9	60.7	35.9	35.4	35.6	6450	6490	662	1.00	2160	2150	2150	89100	13100	6840	6820
04.52	104.0	36.3	49.8	60.0	60.5	60.3	36.5	36.2	36.4	6530	6570	764	0.99	2180	2170	2180	89800	13200	6840	6820
04.56	104.0	36.4	49.7	60.0	60.4	60.2	36.6	36.2	36.4	6530	6570	686	1.00	2180	2170	2180	90200	13200	6840	6820
05.00	104.0	36.3	49.7	59.9	60.4	60.2	36.5	36.2	36.4	6520	6560	688	1.00	2180	2170	2180	90700	13300	6840	6820

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TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos φ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
05 04	104.0	36.4	49 5	59.9	60 4	60.2	36 7	36 2	36.5	6540	6580	724	0.99	2180	2170	2180	91400	13400	6840	6820
05 11	104 0	36 4	49 5	59.8	60.3	60 1	36.6	36.1	36 4	6520	6550	667	1 00	2180	2170	2180	91900	13400	6840	6820
05.15	104.0	36.1	49.3	59.5	60.0	59.8	36 4	35.9	36 1	6440	6470	653	1.00	2150	2140	2150	92300	13500	6840	6820
05 19	102.0	36 6	48 7	58 8	59 3	59 1	36 7	36 5	36 5	6440	6490	730	0.99	2150	2150	2150	93000	13500	6840	6820
05 26	101 0	37 6	48 3	58 3	58.7	58 6	37 6	37.5	37 7	6530	6600	992	0.99	2170	2180	2180	93500	13600	6840	6820
05 30	101 0	37 4	48.3	58 1	58.6	58 4	37 5	37.3	37.5	6480	6550	986	0.99	2150	2160	2160	93900	13700	6840	6820
05.34	101.0	36 5	48 3	58 2	58 7	58 5	36 7	36.4	36 5	6350	6400	791	0 99	2120	2120	2120	94800	13800	6840	6820
05.41	101 0	36 4	48 1	58 1	58 5	58 3	36.5	36 2	36 5	6320	6360	761	0 99	2110	2100	2110	95200	13800	6840	6820
05.45	101.0	36 6	48 0	57 7	58.3	58 0	36 8	36 3	36 7	6320	6360	762	0.99	2110	2100	2120	95600	13900	6840	6820
05.52	101.0	36 6	48 0	57 8	58 4	58 1	36 8	36 4	36 6	6330	6380	786	0.99	2110	2100	2110	96200	14000	6840	6820
05.56	101 0	36 7	48 2	58 2	58.7	58 4	36 9	36 5	36 6	6370	6430	838	0.99	2130	2120	2120	96700	14000	6840	6820
06.00	102.0	37.0	49.1	58 4	59.0	58 7	37 2	36 9	37 0	6470	6520	788	0 99	2150	2160	2160	97100	14100	6840	6820
06.04	102.0	36.9	49 3	58.5	59 1	58 8	37 1	36 8	36.9	6470	6520	782	0 99	2150	2160	2160	97900	14200	6840	6820
06.11	102 0	36 8	49 2	58 3	58 9	58.6	36 9	36 6	36 8	6420	6470	735	0.99	2140	2140	2140	98300	14200	6840	6820
06 15	102 0	37 1	49 1	58.6	59 1	58.8	37 2	36 9	37 1	6490	6540	813	0.99	2170	2160	2160	98700	14300	6840	6820
06.19	101.0	36.7	48 7	58 1	58 7	58.4	36 9	36.6	36 7	6390	6440	775	0.99	2130	2130	2130	99500	14400	6840	6820
06.26	100 0	36.3	48.7	57 6	58.2	57 9	36 6	36 2	36.3	6280	6310	682	0.99	2100	2090	2090	99900	14400	6840	6820
06.30	101.0	37 0	48 6	57.8	58 3	58 0	37 1	36.9	36.9	6380	6430	861	0 99	2120	2130	2120	100300	14500	6840	6820
06.34	99.6	37.6	48 3	57.3	57.8	57 5	37.7	37.5	37 6	6420	6490	950	0.99	2140	2140	2140	101100	14600	6840	6820
06 41	99 4	37 5	48 2	57 1	57.6	57 4	37 6	37 5	37 5	6390	6460	936	0 99	2130	2130	2130	101500	14600	6840	6820
06.45	99.6	37 6	48 3	57.3	57.8	57.5	37 7	37 5	37 6	6420	6490	936	0.99	2140	2140	2140	101900	14700	6840	6820
06.52	98 7	37.3	48.3	56.7	57 2	57 0	37.4	37.2	37 3	6320	6380	828	0.99	2110	2110	2100	102600	14800	6840	6820
06.56	99 0	37.3	48.4	56.9	57.4	57.1	37 4	37.2	37.2	6330	6390	829	0.99	2110	2120	2110	103000	14800	6840	6820
07.00	98.9	37.7	48.5	56.8	57.4	57 1	37 8	37.7	37.7	6410	6470	843	0.99	2130	2140	2140	103600	14900	6840	6820
07.04	99.3	38.0	48 8	57.1	57.6	57.3	38.2	37.9	38 0	6490	6540	795	0.99	2160	2170	2160	104200	15000	6840	6820
07.11	99.6	38.0	48 8	57.3	57.8	57 5	38 1	37.9	38.0	6500	6560	912	0.99	2160	2170	2170	104600	15000	6840	6820
07.15	99.6	38.2	49 1	57.2	57.8	57.5	38.3	38 0	38.1	6530	6580	829	0.99	2180	2180	2180	105200	15100	6840	6820
07.19	99.4	38 3	49.3	57.2	57.6	57.4	38 4	38 1	38.3	6540	6590	788	0.99	2180	2180	2180	105800	15200	6840	6820
07.26	99 5	38.1	49.4	57 2	57.7	57.5	38 2	38 0	38.2	6520	6570	834	0.99	2170	2180	2180	106200	15200	6840	6820
07.30	99.1	38.1	49 5	56.9	57.5	57 2	38 2	37.9	38.0	6480	6530	774	0.99	2160	2160	2160	106900	15300	6840	6820
07.34	98.7	38.2	49 7	56.7	57 2	57 1	38 3	38 0	38.2	6490	6530	729	0.99	2160	2160	2170	107600	15400	6840	6820

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Appendix - 3/1 contd.

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
07.41	98.7	38 1	49 8	56.7	57 3	57.0	38 2	37 9	38.1	6470	6510	701	0.99	2150	2160	2160	108000	15400	6840	6820
07 45	99 0	38.0	49 8	56 8	57 4	57.2	38 1	37.9	38 1	6480	6520	721	0.99	2150	2160	2170	108500	15500	6840	6820
07.52	98.6	37.9	50 1	56.6	57.2	57 0	38.0	37 8	38.0	6440	6470	678	0.99	2140	2150	2150	109100	15600	6840	6820
07.56	99.2	37 6	50.2	57.0	57.5	57.3	37.6	37.6	37.7	6420	6470	796	0.99	2130	2140	2140	109500	15600	6840	6820
08.00	98.6	37 8	50 5	56.6	57.1	57 0	37.8	37.7	37.8	6400	6440	724	0.99	2120	2140	2140	110000	15700	6840	6820
08.04	98 5	37 5	50.2	56 6	57.1	56.9	37.6	37.4	37.6	6360	6400	724	0.99	2110	2120	2130	110700	15700	6840	6820
08.11	98.9	37 5	50.1	56 8	57 4	57.1	37.5	37 3	37.6	6380	6420	690	0.99	2120	2130	2140	111200	15800	6840	6820
08.15	98 6	37.5	50.1	56.6	.57.2	57 0	37 6	37 4	37 6	6370	6410	722	0.99	2110	2120	2130	111600	15800	6840	6820
08.19	98.6	37 6	50 1	56 6	57.2	57.0	37 7	37 5	37.7	6390	6420	698	0.99	2120	2130	2140	112300	15900	6840	6820
08 26	99.1	37.9	50 1	56 9	57.5	57 2	38.0	37 9	38.0	6460	6510	779	0.99	2140	2160	2160	112800	16000	6840	6820
08.30	99.1	37 8	50.2	57.0	57.5	57 3	37.8	37.8	37 9	6450	6500	764	0.99	2140	2160	2160	113200	16000	6840	6820
08.34	99.0	38 1	50.1	56 9	57 4	57.2	38 1	38 0	38.1	6490	6530	716	0.99	2160	2170	2170	114000	16100	6840	6820
08.41	99.5	38.4	50 0	57.2	57 7	57.5	38 3	38.4	38 5	6570	6620	777	0.99	2180	2200	2200	114500	16200	6840	6820
08.45	99.0	38 4	50 1	56 9	57.4	57.2	38 5	38 3	38 4	6550	6590	724	0.99	2180	2190	2180	114900	16200	6840	6820
08.52	99 4	38 2	50 1	57.1	57.6	57 4	38 1	38.1	38.2	6520	6570	784	0.99	2160	2180	2180	115600	16300	6840	6820
08 56	99.1	37 9	50 1	57 0	57 5	57.2	37.9	37.9	38.0	6470	6510	750	0.99	2150	2160	2160	116000	16400	6840	6820
09 00	98 7	38.1	49 8	56.6	57.2	57 0	38 2	38 0	38 1	6470	6510	674	1.00	2150	2160	2160	116400	16400	6840	6820
09.04	98 3	37 9	49 5	56 4	57 0	56 8	38 1	37 8	37 9	6420	6460	647	1.00	2140	2140	2140	117200	16500	6840	6820
09 11	98 8	38.2	49 4	56 7	57 3	57 1	38 3	38 0	38 2	6500	6530	618	1.00	2160	2160	2170	117600	16500	6840	6820
09.15	99 3	38 4	49 4	57.1	57.6	57 3	38.5	38 3	38.4	6560	6600	771	0.99	2180	2190	2190	118100	16600	6840	6820
09.19	99 2	38 3	49.1	57 0	57 5	57 3	38 4	38.1	38 3	6530	6570	764	0 99	2180	2170	2180	118800	16700	6840	6820
09.26	97 8	37 4	49 0	56 2	56 7	56 5	37.6	37 2	37 3	6300	6330	644	1 00	2100	2100	2100	119200	16700	6840	6820
09 30	97 9	39 2	48 9	56 3	56 8	56 5	39 2	39 2	39.2	6590	6650	915	0 99	2190	2200	2200	119700	16800	6840	6820
09 34	98 2	38 5	48 8	56 5	56 9	56 7	38 5	38 4	38 5	6490	6540	860	0 99	2160	2160	2170	120500	16900	6840	6820
09.41	98 2	38 5	48 7	56 4	57 0	56 7	38 5	38 4	38 6	6500	6550	869	0 99	2160	2170	2170	121000	16900	6840	6820
09 45	98.2	38 6	48 8	56 4	56 9	56 7	38 6	38 5	38.7	6510	6560	847	0 99	2160	2170	2170	121400	17000	6840	6820
09 52	97.3	38 3	48 4	55 9	56 4	56 2	38 4	38 2	38 4	6420	6460	741	0.99	2130	2140	2150	122100	17100	6840	6820
09.56	97.3	38 4	48.2	55 9	56 5	56 2	38.6	38 2	38 4	6430	6480	758	0.99	2140	2140	2150	122500	17100	6840	6820
10.00	96 5	38 2	48 0	55 5	56 0	55 8	38 3	38 0	38 2	6340	6390	746	0.99	2110	2110	2120	122900	17200	6840	6820
10.04	96 6	38 1	47 8	55 5	56 0	55 8	38 2	37.9	38.1	6320	6370	748	0 99	2110	2100	2110	123600	17300	6840	6820
10 11	96.1	38 4	48 0	55.2	55 8	55 5	38 5	38 3	38 4	6350	6400	774	0 99	2110	2120	2120	124100	17300	6840	6820

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
10.15	96.9	38.7	47.9	55.7	56.2	56.0	38.8	38.6	38.8	6430	6500	903	0.99	2140	2150	2150	124500	17400	6840	6820
10.19	96.5	38.8	47.9	55.4	55.9	55.8	38.9	38.7	38.8	6420	6480	859	0.99	2130	2140	2150	125200	17500	6840	6820
10.26	96.3	38.8	47.9	55.3	55.8	55.6	38.9	38.7	38.8	6420	6470	805	0.99	2130	2140	2140	125700	17500	6840	6820
10.30	96.4	38.7	47.9	55.4	55.9	55.7	38.8	38.6	38.7	6410	6460	824	0.99	2130	2140	2140	126100	17600	6840	6820
10.34	96.3	38.7	47.9	55.4	55.8	55.6	38.8	38.5	38.6	6390	6450	832	0.99	2130	2130	2130	126900	17700	6840	6820
10.41	96.4	38.7	47.9	55.4	55.9	55.7	38.9	38.6	38.6	6410	6470	863	0.99	2140	2140	2130	127400	17700	6840	6820
10.45	96.6	38.8	47.9	55.5	56.0	55.8	38.9	38.7	38.8	6430	6490	865	0.99	2140	2140	2150	127800	17800	6840	6820
10.52	96.2	38.6	47.9	55.3	55.7	55.6	38.7	38.5	38.6	6380	6430	790	0.99	2120	2130	2130	128500	17900	6840	6820
10.56	96.3	38.7	48.0	55.3	55.8	55.6	38.8	38.7	38.7	6410	6450	761	0.99	2130	2140	2140	128900	17900	6840	6820
11.00	96.3	38.7	48.0	55.3	55.8	55.6	38.8	38.6	38.6	6400	6450	784	0.99	2130	2140	2130	129300	18000	6840	6820
11.04	98.6	39.6	49.7	56.6	57.2	57.0	39.5	39.5	39.7	6700	6760	851	0.99	2220	2240	2250	130100	18100	6840	6820
11.11	98.0	39.2	48.7	56.3	56.9	56.6	39.2	39.1	39.2	6600	6650	805	0.99	2200	2200	2200	130500	18100	6840	6820
11.15	97.2	38.9	48.4	55.8	56.4	56.1	39.0	38.8	38.8	6490	6540	844	0.99	2160	2170	2160	131000	18200	6840	6820
11.19	97.0	39.0	48.4	55.7	56.3	56.0	39.1	39.0	39.0	6500	6560	876	0.99	2160	2170	2170	131700	18300	6840	6820
11.26	97.5	38.9	48.4	56.1	56.6	56.3	39.0	38.9	38.9	6510	6570	927	0.99	2160	2170	2170	132100	18400	6840	6820
11.30	97.3	38.9	48.5	55.9	56.5	56.2	39.0	38.8	38.9	6500	6550	829	0.99	2160	2170	2170	132600	18400	6840	6820
11.34	97.8	38.9	48.6	56.2	56.7	56.5	38.9	38.9	38.9	6520	6590	923	0.99	2170	2180	2170	133400	18500	6840	6820
11.41	97.3	38.9	48.3	56.0	56.5	56.2	38.9	38.8	38.9	6490	6560	913	0.99	2160	2170	2170	133900	18600	6840	6820
11.45	98.0	39.0	48.3	56.3	56.8	56.6	39.0	39.0	39.1	6550	6620	970	0.99	2170	2190	2190	134300	18700	6840	6820
11.52	98.3	39.0	48.6	56.5	57.0	56.8	38.9	39.0	39.0	6570	6640	955	0.99	2180	2200	2190	135000	18800	6840	6820
11.56	98.5	38.9	48.7	56.6	57.1	56.9	38.9	38.9	39.0	6570	6640	967	0.99	2180	2200	2200	135400	18800	6840	6820
12.00	98.7	38.6	48.7	56.7	57.3	57.0	38.7	38.5	38.7	6550	6610	848	0.99	2180	2190	2190	135800	18900	6840	6820
12.04	98.3	38.6	48.7	56.5	57.0	56.8	38.7	38.5	38.7	6530	6580	825	0.99	2170	2170	2180	136600	19000	6840	6820
12.11	98.7	38.3	48.5	56.7	57.2	57.0	38.4	38.1	38.4	6490	6550	883	0.99	2160	2160	2170	137000	19000	6840	6820
12.15	98.6	38.3	48.4	56.6	57.1	56.9	38.5	38.1	38.4	6480	6540	880	0.99	2160	2150	2170	137500	19100	6840	6820
12.19	96.7	38.5	48.2	55.6	56.1	55.9	38.7	38.4	38.4	6400	6450	762	0.99	2140	2140	2130	138200	19200	6840	6820
12.26	96.5	38.8	48.1	55.5	55.9	55.7	39.1	38.6	38.9	6450	6490	720	0.99	2160	2150	2150	138700	19200	6840	6820
12.30	96.3	38.9	48.0	55.3	55.9	55.6	39.2	38.7	38.9	6450	6500	748	0.99	2160	2140	2150	139100	19300	6840	6820
12.34	96.8	39.0	47.9	55.6	56.1	55.9	39.2	38.8	39.0	6490	6540	811	0.99	2170	2160	2160	139900	19400	6840	6820
12.41	96.9	39.1	47.9	55.6	56.1	56.0	39.3	38.9	39.1	6510	6560	772	0.99	2170	2170	2170	140400	19400	6840	6820
12.45	96.8	39.1	48.0	55.6	56.1	55.9	39.4	38.9	39.1	6510	6560	779	0.99	2170	2160	2170	140800	19500	6840	6820

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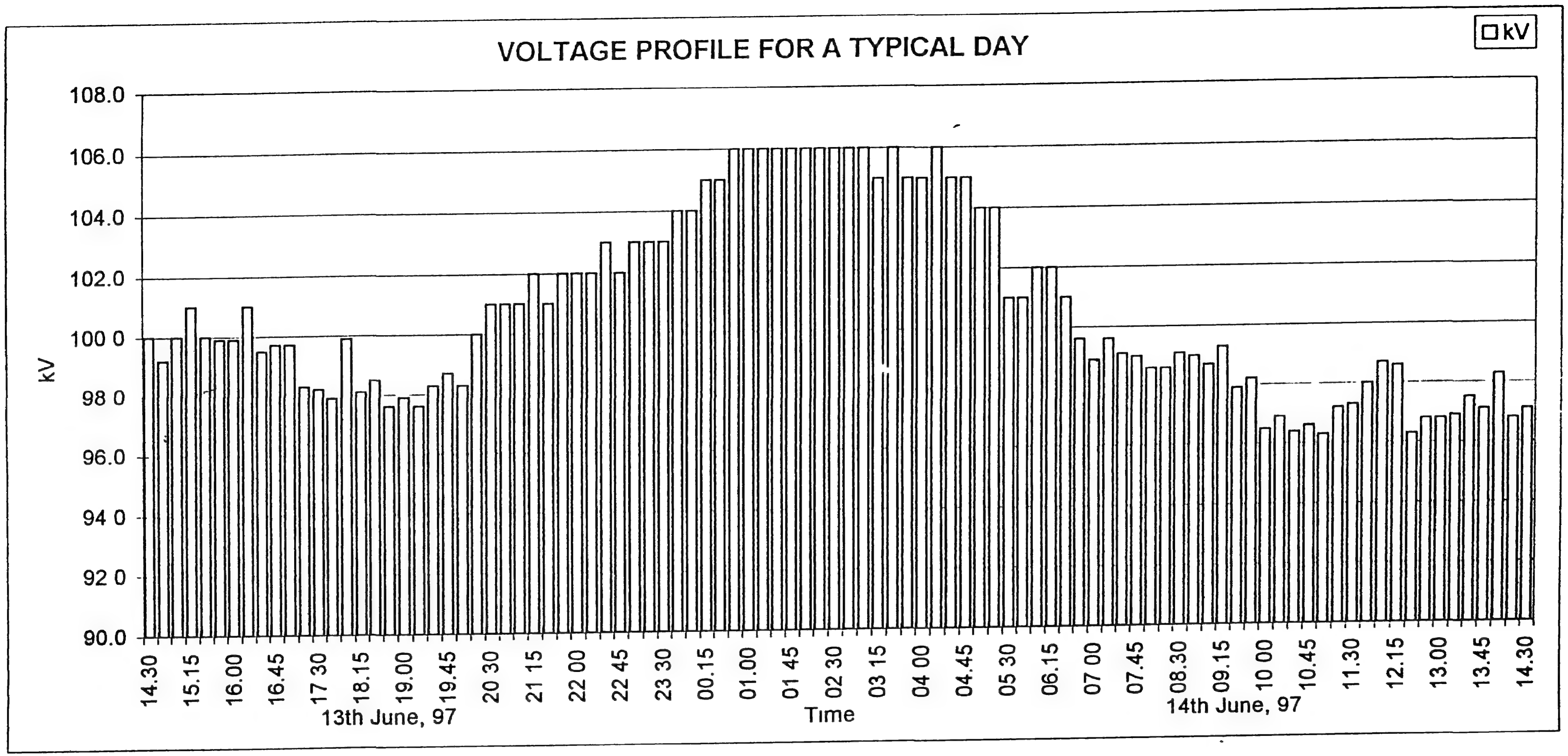
Appendix - 3/1 contd.

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW (R)	kW (Y)	kW (B)	kWh	kVArh	kVA (Peak)	kW (Peak)
12.52	96.5	39.0	47.8	55.4	55.9	55.8	39.2	38.9	39.0	6480	6520	747	0.99	2160	2160	2160	141500	19600	6840	6820
12.56	96.8	39.0	48.0	55.6	56.1	55.9	39.2	38.8	39.0	6500	6540	751	0.99	2170	2160	2170	141900	19600	6840	6820
13.00	96.8	39.1	47.9	55.6	56.1	55.9	39.2	38.9	39.0	6500	6550	819	0.99	2170	2160	2170	142300	19700	6840	6820
13.04	97.0	39.0	48.0	55.8	56.2	56.0	39.1	38.8	39.1	6510	6550	785	0.99	2170	2160	2180	143100	19800	6840	6820
13.11	96.8	39.0	48.1	55.7	56.1	55.9	39.1	38.9	39.0	6490	6540	806	0.99	2160	2160	2170	143500	19800	6840	6820
13.15	96.9	39.0	48.1	55.7	56.2	56.0	39.2	38.9	39.1	6500	6560	844	0.99	2170	2160	2170	144000	19900	6840	6820
13.19	96.8	38.9	48.1	55.6	56.1	56.0	38.9	38.7	38.9	6460	6520	861	0.99	2150	2150	2160	144700	20000	6840	6820
13.26	96.9	38.8	48.2	55.7	56.2	56.0	38.9	38.7	38.7	6460	6510	833	0.99	2150	2150	2150	145200	20000	6840	6820
13.30	97.5	38.9	48.3	56.0	56.5	56.3	39.0	38.8	38.8	6510	6560	827	0.99	2160	2170	2170	145600	20100	6840	6820
13.34	97.2	38.9	47.9	55.9	56.4	56.1	39.1	38.8	38.9	6490	6560	947	0.99	2160	2160	2160	146400	20200	6840	6820
13.41	96.8	38.6	47.9	55.6	56.1	55.9	38.8	38.6	38.6	6420	6480	874	0.99	2140	2140	2140	146900	20300	6840	6820
13.45	97.1	38.8	47.9	55.8	56.2	56.1	39.0	38.7	38.8	6470	6520	865	0.99	2150	2160	2160	147300	20300	6840	6820
13.52	96.9	39.0	47.9	55.7	56.2	56.0	39.1	38.8	39.0	6490	6550	882	0.99	2160	2160	2170	148000	20400	6840	6820
13.56	97.1	38.9	48.1	55.8	56.2	56.1	38.9	38.7	39.0	6470	6530	875	0.99	2160	2150	2170	148400	20500	6840	6820
14.00	98.3	39.0	48.3	56.5	57.0	56.8	39.1	38.8	39.1	6570	6640	927	0.99	2190	2190	2200	148800	20500	6840	6820
14.04	97.3	38.9	48.1	55.9	56.4	56.2	39.1	38.6	39.0	6510	6560	773	0.99	2180	2160	2180	149600	20600	6840	6820
14.11	96.9	39.1	48.1	55.7	56.2	56.0	39.3	38.8	39.1	6510	6550	745	0.99	2180	2160	2170	150000	20700	6840	6820
14.15	96.8	39.0	48.0	55.7	56.1	55.9	39.3	38.7	39.1	6500	6550	772	0.99	2170	2150	2180	150500	20700	6840	6820
14.19	96.5	39.0	47.9	55.5	55.9	55.7	39.3	38.7	39.0	6470	6510	753	0.99	2160	2150	2160	151200	20800	6840	6820
14.26	96.9	39.2	48.0	55.7	56.2	56.0	39.4	38.9	39.2	6530	6580	820	0.99	2180	2170	2180	151600	20900	6840	6820
14.30	97.1	26.1	47.9	55.8	56.2	56.1	39.3	38.9	39.1	4350	4380	550	0.99	2170	2150	2180	152100	20900	6840	6820



TATA ENERGY RESEARCH INSTITUTE
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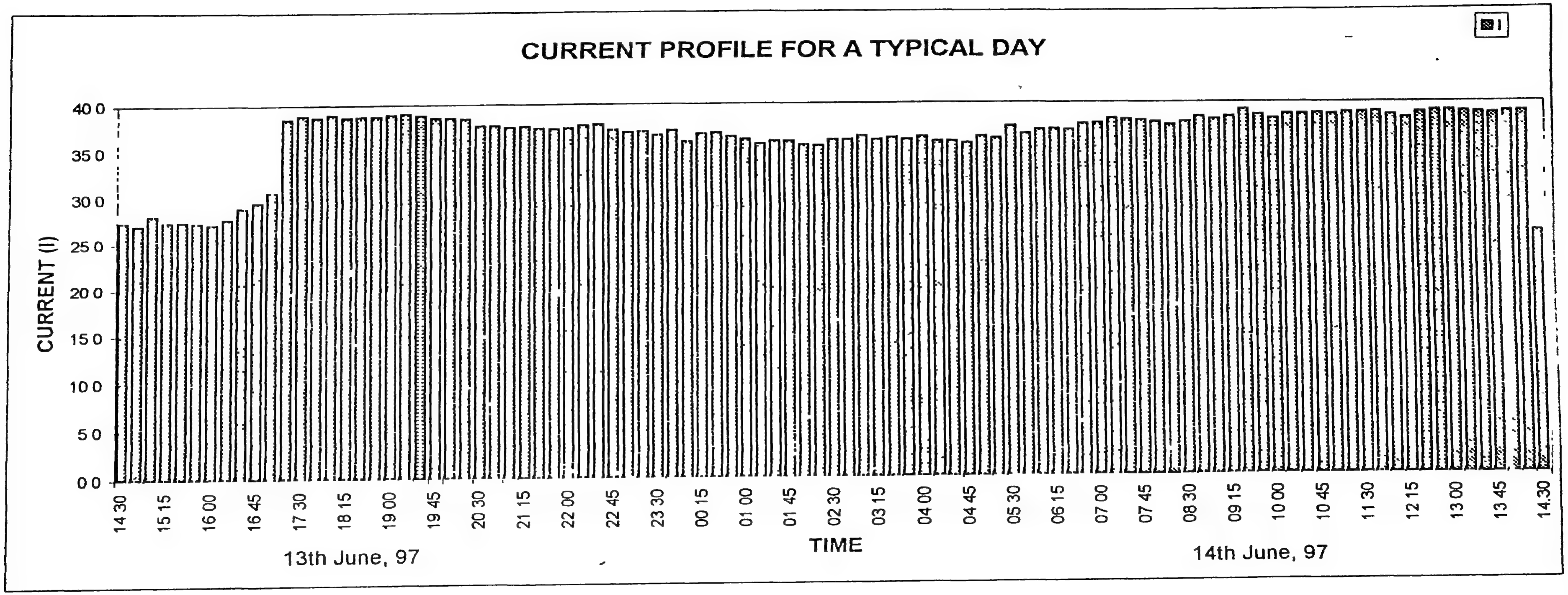
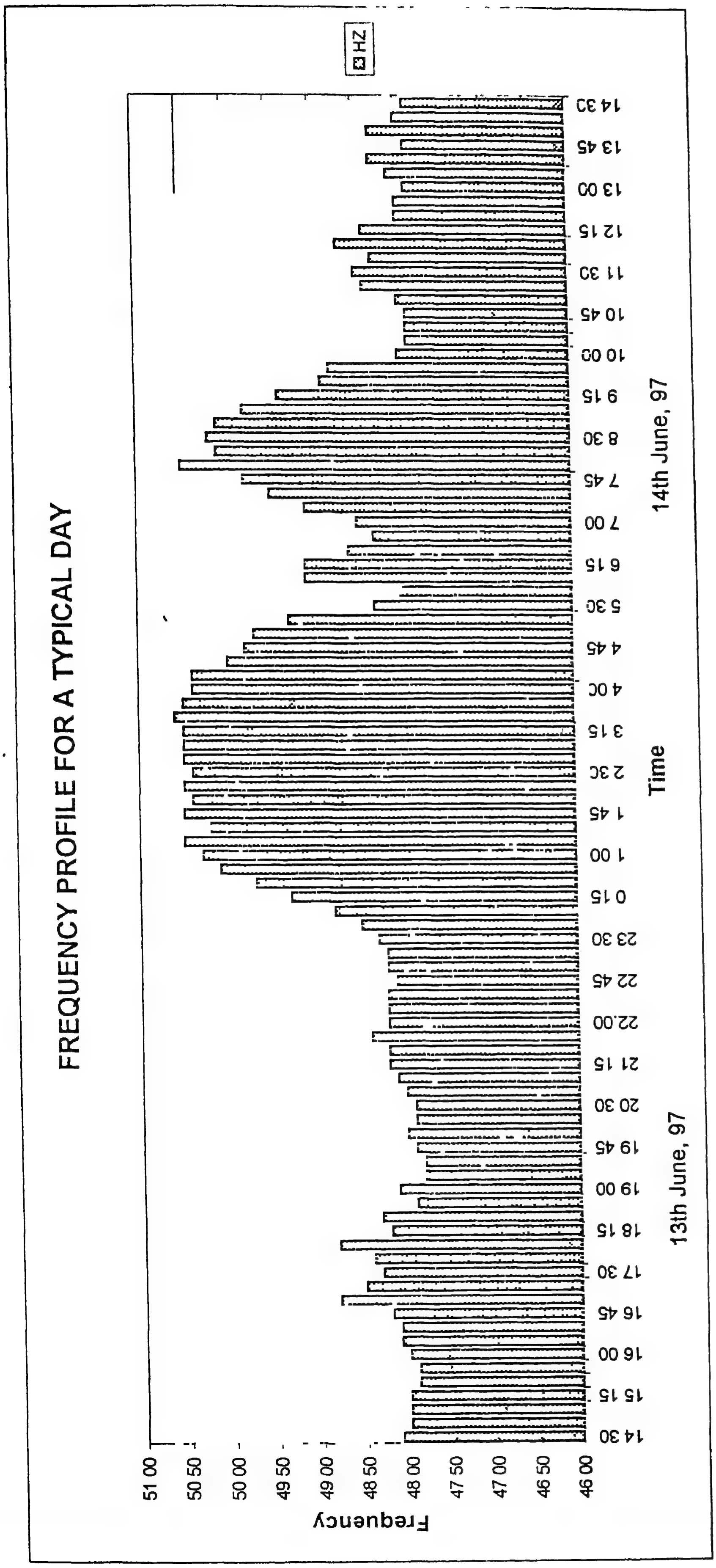
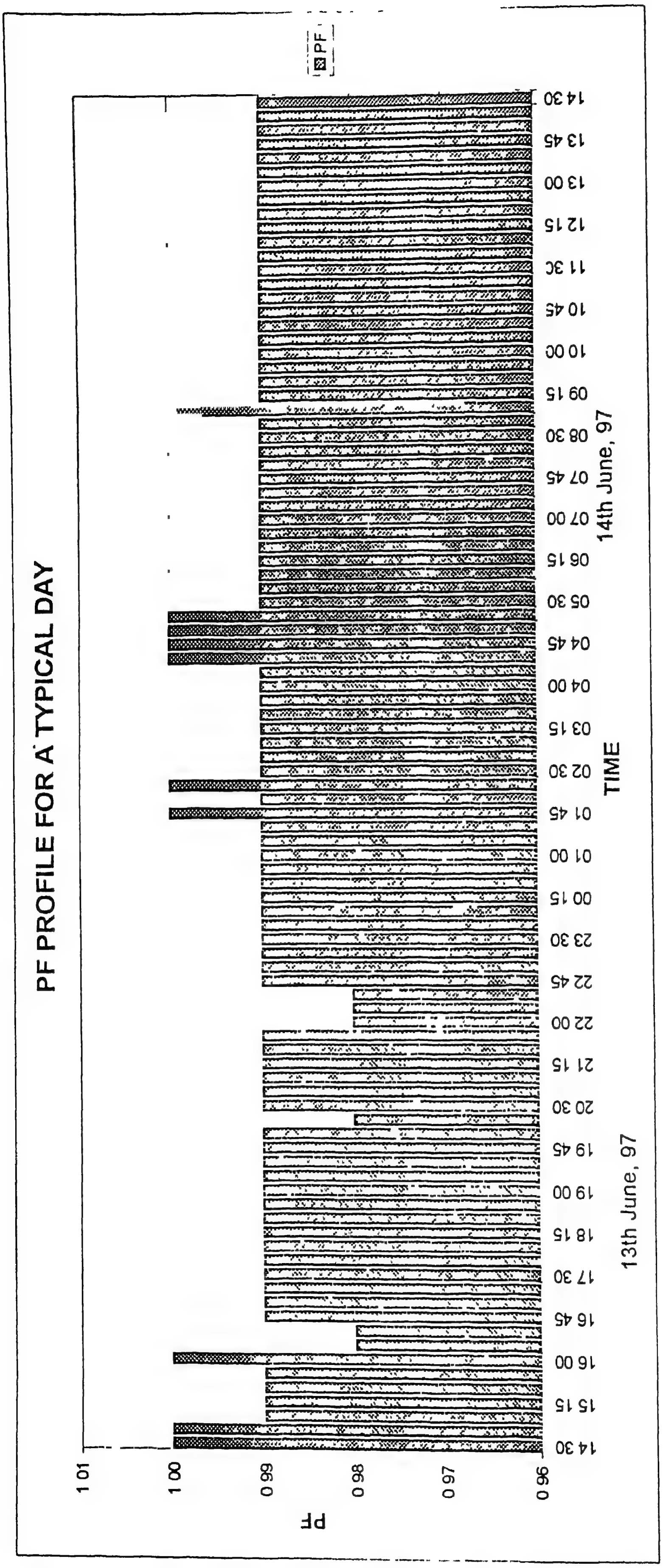
APPENDIX - 3/1b

CURRENT PROFILE FOR A TYPICAL DAY

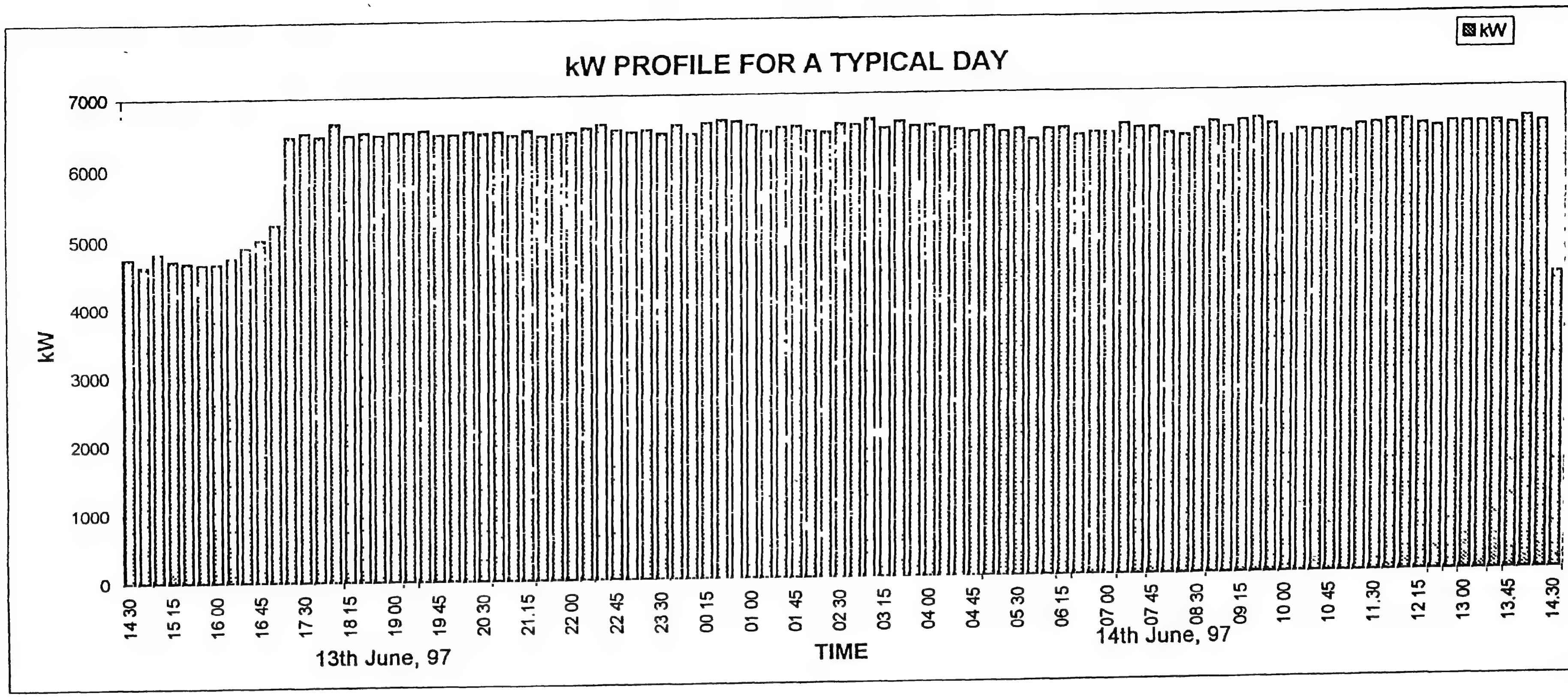



FREQUENCY PROFILE FOR A TYPICAL DAY
HZ
Frequency
51 00
50 50
50 00
49 50
49 00
48 50
48 00
47 50
47 00
46 50
46 00
14 30
15 15
16 00
16 45
17 30
18 15
19 00
19 45
20 30
21 15
22.00
22 45
23 30
0 15
1 00
1 45
2 30
3 15
4 00
4 45
5 30
6 15
7 00
7 45
8 30
9 15
10 00
10 45
11 30
12 15
13 00
13 45
14 30
Time
13th June, 97
14th June, 97

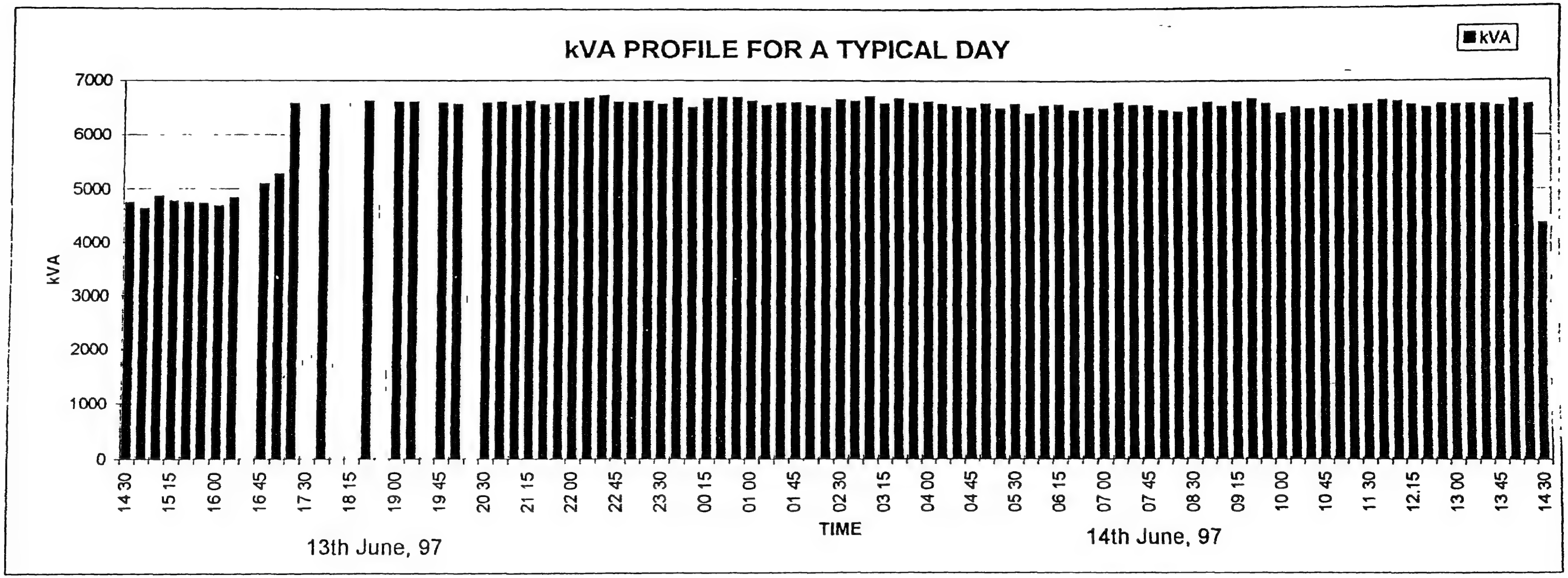
APPENDIX - 3/1d



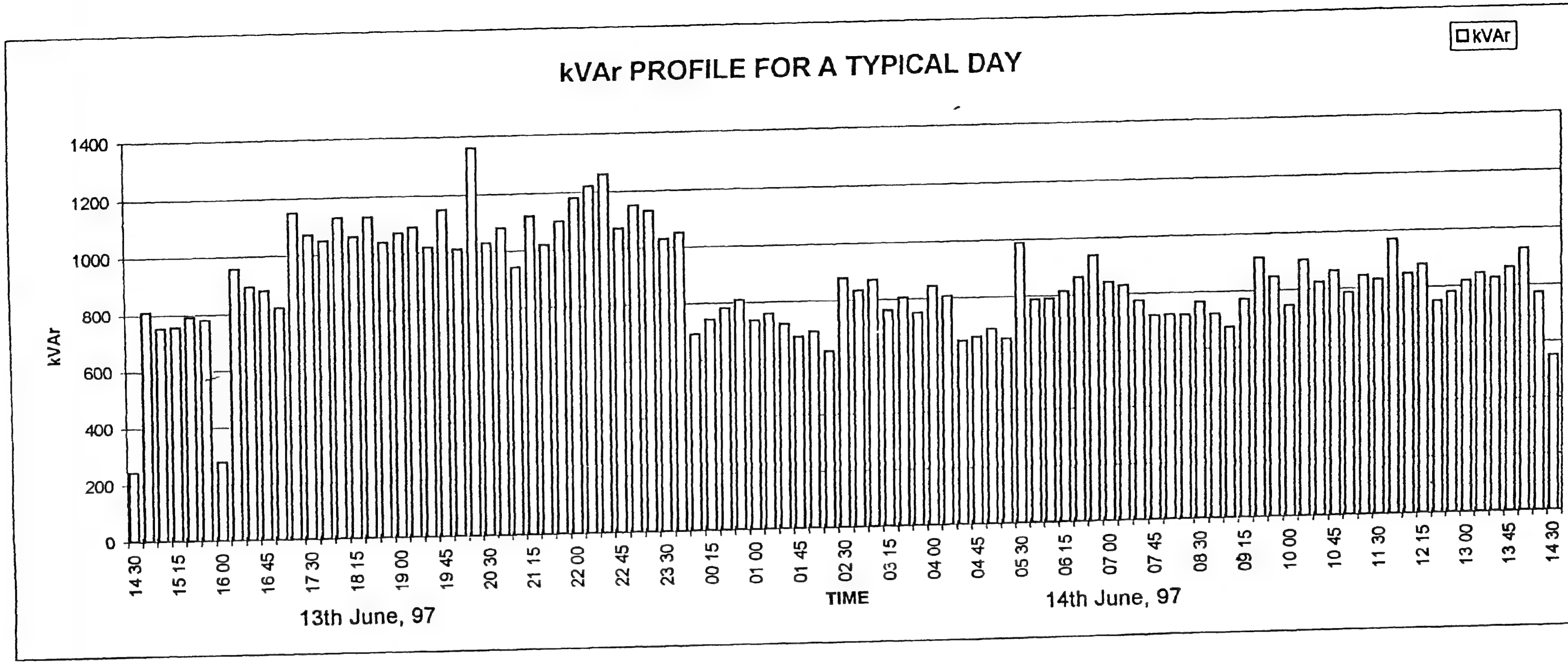
APPENDIX - 3/1e



APPENDIX - 3/1f



APPENEIX - 3/1g



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APPENDIX - 3/2

ELECTRICITY CONSUMPTION DETAILS FOR THE YEAR 1996 - 1997

Sl. No.	MONTH	ENERGY CONSUMPION IN Lakh kWh
1	April ' 96	38 99
2	May ' 96	42 25
3	June ' 96	43 87
4	July ' 96	46 37
5	Aug ' 96	48 64
6	Sept ' 96	44 66
7	Oct ' 96	47 56
8	Nov ' 96	47 49
9	Dec ' 96	44 31
10	Jan ' 97	47 09
11	Feb ' 97	31.63
12	Mar ' 97	34 54

APPENDIX - 3/3

CAPACITOR INSTALLED DETAILS

DESCRIPTION	CAPACITOR INSTALLED CAPACITY IN kVAr
22 kV Switchyard	2100 kVAr (OLD)
	6087 kVAr (NEW)
LT 415 V	
PCC PANEL	185kVAr
MCC - 1	30kVAr
MCC - 4	50kVAr
MCC - 5	110kVAr
MCC - 6	25kVAr
MCC - 7	65kVAr
MCC - 10	30kVAr

APPENDIX - 3/4

CELL HOUSE # 1 INCOMING 22kV MEASUREMENT DETAILS

DATE : 17th,June '97

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh	kVArh	kVA(Peak)	kW(Peak)
11.10	21.8	35.2	48.4	12.2	12.8	12.6	19.4	102.8	42.4	732	1324	1100	0.56	187	148	398	0	0	3616	3248
11.15	21.6	99.6	48.7	12.1	12.7	12.5	99.0	98.4	101.2	3384	3712	1532	0.91	1084	1152	1148	120	40	3616	3248
11.20	21.4	98.4	48.2	12.0	12.6	12.4	98.0	97.0	100.0	3324	3632	1464	0.92	1068	1128	1128	520	200	3616	3248
11.25	21.4	98.4	48.2	12.0	12.6	12.4	98.0	97.2	100.2	3328	3648	1496	0.91	1068	1132	1128	720	320	3616	3248
11.30	21.4	98.0	48.2	12.0	12.6	12.4	97.8	96.8	99.6	3312	3624	1472	0.91	1060	1128	1124	960	400	3616	3248
11.35	21.2	97.2	47.9	11.9	12.5	12.3	96.8	95.8	99.0	3268	3572	1440	0.92	1048	1108	1112	1400	600	3616	3248
11.40	21.2	98.0	48.1	11.9	12.6	12.3	97.6	96.4	99.8	3304	3604	1436	0.92	1060	1124	1124	1600	720	3616	3248
11.45	21.6	99.6	48.1	12.1	12.7	12.5	98.8	98.6	101.6	3364	3712	1564	0.91	1072	1152	1140	1840	800	3616	3248
11.50	21.4	100.6	48.1	12.0	12.6	12.4	100.0	99.2	102.8	3420	3724	1476	0.92	1092	1164	1164	2160	960	3616	3268
11.55	21.2	98.2	48.1	11.9	12.5	12.3	97.8	96.8	99.8	3324	3608	1408	0.92	1064	1128	1128	2400	1040	3616	3268
12.00	21.2	98.4	48.4	12.0	12.6	12.3	98.2	97.0	100.2	3340	3628	1416	0.92	1072	1136	1132	2600	1160	3616	3268
12.05	21.6	101.0	48.2	12.1	12.7	12.5	100.6	99.8	102.8	3428	3764	1548	0.91	1096	1168	1164	3000	1320	3620	3304
12.10	21.4	100.2	48.1	12.0	12.6	12.4	99.6	98.8	102.2	3388	3712	1516	0.91	1084	1152	1152	3240	1400	3620	3304
12.15	21.4	99.4	48.1	12.0	12.6	12.4	99.0	98.2	101.6	3360	3680	1500	0.91	1076	1144	1140	3440	1520	3628	3336
12.20	21.4	99.4	48.0	12.0	12.6	12.4	98.8	98.0	101.4	3364	3676	1484	0.92	1076	1144	1144	3840	1680	3636	3340
12.25	21.4	98.8	48.1	12.0	12.6	12.4	98.6	97.6	100.6	3344	3648	1464	0.92	1072	1140	1132	4080	1800	3640	3340
12.30	21.4	99.6	48.1	12.0	12.6	12.4	99.0	98.0	101.6	3364	3672	1472	0.92	1076	1144	1144	4320	1880	3640	3340
12.35	21.4	100.8	48.0	12.1	12.7	12.5	100.0	99.6	103.2	3412	3752	1564	0.91	1088	1160	1160	4760	2080	3644	3340
12.40	21.6	101.6	48.0	12.1	12.7	12.5	100.8	100.4	103.6	3444	3792	1588	0.91	1100	1176	1168	5000	2200	3644	3340
12.45	22.4	105.4	48.0	12.6	13.2	13.0	104.4	104.0	107.4	3560	4080	1992	0.87	1132	1220	1204	5200	2320	3652	3368
12.50	22.4	103.6	47.9	12.5	13.2	13.0	102.6	102.4	105.8	3480	4000	1988	0.87	1104	1196	1180	5560	2520	3712	3420
12.55	22.4	103.8	48.0	12.5	13.2	12.9	102.6	102.8	106.0	3492	4000	1972	0.87	1108	1200	1180	5800	2640	3784	3480
13.00	22.4	103.4	47.9	12.5	13.2	12.9	102.4	102.4	105.6	3476	3996	1964	0.87	1104	1196	1180	6040	2760	3784	3480
13.05	21.6	102.2	48.0	12.2	12.8	12.6	101.0	101.2	104.4	3456	3836	1668	0.90	1100	1184	1172	6440	3000	3924	3544
13.10	21.6	101.4	48.0	12.1	12.8	12.5	100.4	100.4	104.0	3436	3796	1616	0.91	1092	1176	1164	6760	3120	3924	3544
13:40	21.6	100.8	48.1	12.1	12.7	12.5	100.0	100.0	102.8	3408	3760	1588	0.91	1088	1168	1152	6880	3200	3936	3548

TATA ENERGY RESEARCH INSTITUTE
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CELL HOUSE # 2 INCOMING 22kV MEASUREMENT DETAILS

DATE : 16th,June '97

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh	kVArh	kVA(Peak)	kW(Peak)
14.30	21.6	63.2	48.0	12.5	12.6	12.4	63.0	63.6	63.2	2244	2372	768	0.95	740	756	744	120	40	2516	2404
14.34	21.8	64.6	47.8	12.5	12.6	12.5	64.4	65.0	64.6	2304	2428	760	0.95	764	776	764	240	80	2516	2404
14.38	21.6	70.8	48.0	12.5	12.6	12.4	70.4	71.2	70.6	2500	2648	872	0.94	828	844	828	480	160	2516	2404
14.42	21.6	71.8	47.9	12.4	12.5	12.4	71.6	72.2	71.6	2544	2684	852	0.95	844	856	844	680	240	2516	2404
14.46	21.6	76.4	47.9	12.4	12.5	12.4	76.0	77.4	75.6	2664	2852	1024	0.93	884	904	876	840	280	2516	2404
14.53	21.6	78.2	47.9	12.5	12.6	12.4	78.0	79.4	77.6	2744	2936	1048	0.93	908	932	900	1120	400	2516	2404
14.57	21.6	78.4	47.9	12.5	12.6	12.4	78.0	79.4	77.6	2744	2936	1040	0.94	912	932	900	1360	480	2516	2404
15.00	21.6	78.4	47.9	12.5	12.6	12.5	78.0	79.6	77.8	2748	2948	1060	0.93	912	936	904	1520	560	2712	2600
15.06	21.8	78.8	47.8	12.5	12.6	12.5	78.4	79.8	78.0	2756	2960	1076	0.93	916	936	904	1800	640	2800	2688
15.10	21.6	78.4	47.9	12.5	12.6	12.4	78.0	79.6	77.8	2744	2940	1060	0.93	908	932	900	2040	760	2832	2760
15.14	21.6	78.6	47.9	12.4	12.5	12.4	78.2	79.6	78.0	2744	2940	1052	0.93	912	932	904	2240	800	2832	2760
15.18	21.6	78.2	48.0	12.4	12.5	12.4	77.8	79.4	77.8	2736	2928	1048	0.93	908	928	900	2520	920	2852	2776
15.23	21.6	78.4	48.0	12.4	12.5	12.4	78.0	79.6	77.8	2740	2932	1048	0.93	908	932	900	2720	1000	2856	2776
15.27	21.6	78.6	48.0	12.5	12.6	12.4	78.0	79.8	77.8	2740	2944	1072	0.93	908	932	900	2920	1080	2856	2776
15.34	21.6	78.2	47.8	12.4	12.5	12.4	77.8	79.4	77.6	2728	2916	1028	0.94	904	928	896	3200	1200	2856	2776
15.38	21.6	78.0	47.9	12.4	12.5	12.4	77.6	79.2	77.6	2724	2912	1024	0.94	904	924	896	3400	1280	2856	2776
15.42	21.4	78.0	47.9	12.4	12.5	12.3	77.6	79.0	77.4	2716	2896	1004	0.94	900	924	896	3600	1320	2856	2776
15.49	21.4	78.0	47.9	12.4	12.5	12.3	77.8	79.0	77.4	2720	2900	1004	0.94	904	924	896	3840	1440	2856	2776
15.53	21.6	78.4	48.0	12.4	12.5	12.4	78.0	79.6	77.8	2732	2932	1064	0.93	904	928	896	4040	1520	2856	2776
15.57	21.6	78.4	48.2	12.5	12.5	12.4	78.0	79.4	77.8	2732	2932	1064	0.93	908	928	896	4240	1560	2856	2776
16.04	21.6	78.4	48.0	12.4	12.5	12.4	77.8	79.6	77.6	2728	2928	1060	0.93	904	928	896	4560	1720	2856	2776
16.08	21.6	78.4	48.0	12.4	12.5	12.4	77.8	79.4	77.6	2728	2920	1048	0.93	904	924	896	4720	1760	2856	2776
16.12	21.4	78.0	48.0	12.4	12.4	12.3	77.6	78.8	77.4	2712	2896	1012	0.94	900	916	896	4920	1840	2856	2776
16.19	21.4	77.8	47.9	12.3	12.4	12.3	77.4	78.6	77.6	2708	2876	960	0.94	896	916	896	5240	1960	2856	2776
16.23	21.4	77.8	47.9	12.3	12.4	12.2	77.4	78.4	77.6	2708	2868	948	0.94	896	916	896	5400	2040	2856	2776
16.30	21.2	77.2	47.9	12.2	12.3	12.2	77.0	77.8	77.0	2684	2840	932	0.95	888	904	888	5600	2080	2856	2776

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22 kV INCOMING MEASUREMENT DETAILS

DATE : 16th,June '97

TIME	kV	I	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	I(B)	kW	kVA	kVAr	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh	kVArh	kVA(Peak)	kW(Peak)
17.00	21.6	194.3	48.1	13.7	13.8	13.7	194.5	194.0	193.8	7920	7975	1067	0.99	2646	2657	2629	0	0	7755	7755
17.04	21.6	193.8	48.3	13.7	13.8	13.7	194.3	193.8	193.0	7920	7975	1001	0.99	2646	2657	2624	485	24	7755	7755
17.08	21.4	192.0	48.1	13.6	13.7	13.6	192.8	192.0	191.8	7810	7865	875	0.99	2602	2607	2591	825	55	7755	7755
17.14	21.4	191.8	48.1	13.6	13.6	13.5	192.3	191.5	191.8	7755	7810	869	0.99	2591	2596	2580	1320	110	7755	7755
17.18	21.4	192.3	48.0	13.6	13.7	13.6	192.8	192.0	191.8	7810	7865	935	0.99	2602	2613	2585	1980	220	7755	7755
17.22	21.4	191.8	47.9	13.6	13.7	13.5	192.3	191.5	191.8	7755	7810	847	0.99	2591	2596	2574	2750	275	7755	7755
17.28	21.4	191.0	48.0	13.6	13.7	13.5	191.5	190.5	191.3	7755	7810	798	1.00	2585	2591	2569	3300	330	7755	7755
17.32	21.2	190.3	47.9	13.5	13.6	13.4	191.0	189.5	190.5	7700	7700	781	1.00	2563	2563	2552	3960	440	7755	7755
17.36	21.4	192.0	47.9	13.6	13.7	13.6	192.5	191.3	191.8	7810	7810	847	0.99	2602	2602	2585	4785	495	7755	7755
17.42	21.4	191.0	47.9	13.5	13.6	13.5	191.8	190.5	191.3	7755	7755	776	1.00	2580	2580	2569	5280	550	7755	7755
17.46	21.4	192.0	47.9	13.6	13.6	13.5	192.8	191.3	192.0	7755	7810	798	0.99	2596	2596	2580	5830	605	7755	7755
17.50	21.4	191.0	47.9	13.5	13.6	13.5	191.8	190.5	191.0	7700	7755	787	1.00	2574	2574	2563	6600	715	7755	7755
17.56	21.4	192.5	48.1	13.5	13.6	13.5	193.0	191.8	192.5	7810	7810	781	1.00	2596	2596	2591	7095	770	7755	7755
18.00	21.4	192.5	48.3	13.6	13.7	13.6	193.0	192.3	192.3	7810	7865	847	0.99	2607	2613	2596	7645	825	7755	7755
18.04	21.6	190.8	48.3	13.7	13.8	13.6	191.0	191.3	190.3	7755	7810	930	0.99	2591	2607	2569	8525	935	7755	7755
18.10	21.8	191.3	48.3	13.8	13.9	13.8	191.0	191.8	190.3	7865	7920	1161	0.99	2613	2635	2591	9075	990	7755	7755
18.14	22.0	188.5	48.2	13.9	14.0	13.9	188.3	188.5	187.8	7810	7865	1155	0.99	2596	2618	2585	9570	1045	7755	7755
18.18	21.6	189.8	48.1	13.6	13.7	13.7	189.8	190.0	189.3	7700	7755	979	0.99	2569	2585	2563	10505	1210	7755	7755
18.24	21.4	190.8	48.0	13.6	13.7	13.6	190.3	191.0	190.5	7755	7810	897	0.99	2569	2596	2574	11000	1265	7755	7755
18.28	21.4	188.3	48.2	13.6	13.7	13.6	188.8	189.0	187.5	7645	7700	814	0.99	2547	2574	2536	11495	1320	7755	7755
18.32	21.2	188.8	47.9	13.4	13.5	13.4	189.3	188.5	188.8	7590	7590	721	1.00	2519	2536	2514	12485	1430	7755	7755
18.38	21.0	187.5	48.0	13.4	13.5	13.3	188.0	187.3	187.8	7535	7535	660	1.00	2503	2514	2492	13035	1430	7755	7755
18.42	21.2	193.5	48.0	13.5	13.6	13.4	193.8	193.8	192.8	7810	7865	913	0.99	2596	2613	2574	13530	1485	7755	7755
18.46	21.2	193.5	47.9	13.4	13.6	13.4	193.8	193.8	192.8	7755	7810	946	0.99	2585	2607	2569	14300	1595	7755	7755
18.52	21.2	193.5	47.9	13.4	13.5	13.4	194.0	193.8	192.5	7755	7810	897	0.99	2580	2602	2558	14850	1650	7755	7755
18.56	21.2	192.5	48.3	13.4	13.5	13.4	193.0	193.0	191.0	7700	7755	792	0.99	2569	2596	2541	15345	1705	7755	7755
19.00	21.4	193.8	48.4	13.5	13.6	13.5	194.0	194.3	192.8	7810	7865	913	0.99	2602	2624	2580	16225	1815	7755	7755

TATA ENERGY RESEARCH INSTITUTE
BANGALORE

415 V LT POWER SYSTEM MEASUREMENT DETAILS

DATE : 12th & 13th, June '97

APPENDIX - 3/7

TIME	V	I	Hz	V(R)	V(Y)	V(B)	I(R)	I(Y)	I(B)	kW	kVA	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh
17 00	401	1080	48 5	231	232	232	1050	1113	1080	741	750	0 99	239	254	249	4758
17 04	400	1047	48 4	230	232	231	1017	1077	1047	717	726	0 99	230	246	241	4806
17 11	402	1077	48 5	232	233	232	1053	1101	1077	741	750	0 99	240	253	249	4893
17 15	401	1098	48 6	231	232	232	1074	1122	1095	753	762	0 99	245	257	253	4941
17 19	403	1092	48 6	232	234	233	1071	1116	1095	756	765	0 99	245	257	254	4992
17 26	400	1152	48 5	230	231	231	1131	1167	1155	786	795	0 99	256	266	265	5082
17 30	399	1164	48 5	229	231	231	1146	1188	1158	792	804	0 99	258	270	265	5136
17 34	397	1149	48 5	228	230	229	1131	1173	1140	780	789	0 99	254	265	260	5190
17 41	397	1287	48 5	228	230	229	1263	1314	1281	870	882	0 98	282	296	291	5298
17 45	394	1341	48 5	226	228	228	1314	1377	1338	903	915	0 99	291	309	303	5358
17 49	397	1344	48 6	228	230	229	1311	1380	1338	909	924	0 98	293	312	303	5418
17 56	393	1371	48 8	226	228	227	1341	1410	1365	918	933	0 98	296	315	306	5508
18 00	392	1359	48 8	226	227	227	1329	1392	1350	909	924	0 98	294	312	303	5568
18 04	392	1365	48 7	225	227	226	1335	1401	1362	912	927	0 98	294	312	306	5631
18 11	398	1359	48 7	229	230	230	1332	1404	1347	921	936	0 98	298	318	306	5736
18 15	400	1356	48 7	230	231	231	1329	1398	1341	921	939	0 98	298	315	306	5796
18 19	400	1377	48 6	230	231	231	1353	1416	1362	933	954	0 98	303	321	312	5859
18 26	397	1383	48 6	229	230	229	1362	1425	1365	933	951	0 98	303	321	309	5970
18 30	396	1383	48 3	228	229	229	1359	1428	1362	927	948	0 98	303	318	309	6033
18.34	396	1380	48 5	228	229	229	1359	1425	1359	927	945	0.98	303	318	309	6093
18 41	395	1383	48 3	227	228	228	1359	1431	1359	927	945	0.98	300	318	306	6213
18 45	393	1353	48.1	226	227	227	1332	1401	1326	903	921	0 98	294	312	298	6276
18 49	396	1356	48 2	228	229	229	1335	1404	1335	912	933	0 98	297	315	303	6336
18 56	393	1398	48 2	226	227	227	1377	1449	1365	930	951	0 98	303	321	306	6429
19 00	392	1395	48 2	226	227	227	1377	1449	1359	927	948	0 98	303	321	306	6492
19.04	395	1377	48.1	228	229	229	1350	1428	1350	921	942	0.98	299	318	306	6555
19 11	403	1371	48.2	232	233	233	1350	1425	1347	939	957	0.98	306	324	312	6663
19.15	405	1350	48 2	233	234	234	1329	1401	1323	924	945	0.98	300	318	306	6723

Appendix - 3/7 contd..

TIME	V	I	Hz	V(R)	V(Y)	V(B)	I(R)	I(Y)	I(B)	kW	kVA	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh
19.19	406	1344	48 1	234	235	234	1317	1395	1320	921	945	0.98	298	318	306	6786
19 26	397	·1395	48 0	229	230	230	1368	1446	1377	939	960	0.98	303	324	312	6894
19 30	401	1362	48 1	230	232	232	1332	1413	1344	924	945	0 98	298	318	309	6957
19 34	403	1365	48 1	232	233	233	1335	1413	1347	930	951	0.98	300	321	309	7020
19.41	405	1374	48 2	233	234	234	1350	1419	1353	942	963	0.98	306	324	312	7140
19 45	406	1374	48 3	234	235	235	1353	1419	1347	942	966	0 98	306	324	312	7203
19 49	404	1371	48 4	232	234	233	1350	1416	1347	939	957	0 98	306	324	309	7263
19 56	402	1386	48 4	231	233	232	1362	1437	1359	945	963	0 98	306	327	312	7359
20 00	401	1377	48 3	231	232	232	1353	1428	1353	936	957	0.98	303	324	309	7419
20 04	403	1350	48 3	232	233	233	1320	1401	1329	924	942	0 98	298	318	306	7482
20 11	404	1335	48 4	233	234	233	1305	1392	1311	912	933	0 98	294	318	303	7590
20 15	405	1338	48 4	233	235	234	1314	1389	1314	918	939	0 98	297	315	306	7653
20 19	413	1338	48.4	238	239	239	1317	1383	1320	936	957	0 98	303	321	309	7716
20 26	412	1335	48 3	237	239	238	1308	1389	1311	930	954	0 98	300	321	306	7824
20 30	416	1329	48 2	239	241	240	1308	1377	1299	933	957	0 98	303	321	309	7887
20 34	411	1362	48 2	236	238	238	1341	1404	1344	948	972	0 98	309	324	315	7950
20 41	417	1332	48 2	239	241	241	1311	1368	1314	936	960	0 98	303	321	312	8070
20 45	403	1419	48 2	232	233	233	1398	1467	1398	966	993	0 97	312	330	321	8136
20 49	403	1425	48 2	231	233	233	1398	1473	1404	963	993	0 97	312	330	321	8199
20 56	404	1416	48 3	232	234	234	1386	1461	1401	960	990	0 97	309	330	321	8295
21 00	409	1410	48 4	235	236	237	1383	1455	1389	966	999	0 97	312	333	321	8361
21 04	411	1413	48 6	236	238	238	1377	1464	1401	978	1008	0 97	315	336	327	8424
21 11	407	1413	48 5	234	235	235	1380	1461	1398	966	993	0 97	312	333	324	8541
21 15	408	1389	48 4	234	236	236	1353	1437	1377	951	981	0 97	306	327	318	8604
21 19	406	1416	48 5	233	235	235	1386	1461	1404	966	996	0 97	312	333	324	8667
21 26	408	1407	48 6	235	236	236	1374	1455	1395	969	996	0 97	312	333	324	8784
21 30	408	1407	48 6	234	236	236	1380	1446	1392	969	993	0 98	315	330	324	8847
21 34	409	1398	48 6	235	237	237	1365	1446	1383	963	990	0 97	309	330	321	8913
21 41	405	1404	48 6	233	235	235	1374	1452	1386	963	987	0 98	312	330	321	9039
21 45	405	1410	48 5	233	234	234	1380	1461	1389	963	987	0 97	312	333	321	9102
21 49	406	1386	48 4	233	235	235	1362	1437	1365	948	975	0 97	306	327	315	9168

Appendix - 3/7 contd..

TIME	V	I	Hz	V(R)	V(Y)	V(B)	I(R)	I(Y)	I(B)	kW	kVA	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh
21 56	406	1410	48 6	234	235	235	1383	1458	1395	969	993	0 98	312	333	321	9264
22 00	407	1416	48 6	234	236	235	1389	1467	1398	972	996	0 97	315	336	321	9327
22 04	412	1404	48 8	237	238	238	1377	1443	1392	972	1002	0 97	315	333	327	9393
22 11	410	1410	48 8	236	237	237	1380	1458	1389	972	999	0 97	315	336	324	9507
22 15	410	1386	48 9	236	237	237	1362	1431	1371	963	984	0.98	312	330	321	9570
22 19	410	1395	48 7	236	237	237	1368	1437	1380	963	990	0 97	312	330	321	9633
22 26	407	1371	48 6	234	236	236	1338	1422	1353	939	966	0 97	303	324	312	9747
22 30	408	1401	48 7	235	236	236	1371	1449	1386	963	990	0 97	312	333	321	9810
22 34	408	1383	48 5	234	236	236	1353	1431	1371	948	978	0 97	306	327	318	9873
22 41	409	1398	48 6	235	236	236	1368	1446	1380	963	987	0 98	312	333	321	9999
22 45	409	1404	48 6	235	237	236	1377	1452	1383	969	993	0 97	312	333	321	10065
22 49	410	1413	48 8	236	237	237	1383	1461	1398	978	1005	0 97	315	336	327	10128
22 56	410	1413	48 8	236	237	237	1386	1461	1398	978	1005	0 97	315	336	327	10227
23 00	411	1401	48 8	236	238	238	1368	1449	1386	969	996	0 97	312	333	324	10290
23 04	412	1380	48 9	237	238	239	1347	1431	1365	957	984	0 97	309	330	321	10356
23 11	413	1407	49 2	237	239	239	1377	1455	1389	978	1005	0 97	315	336	327	10470
23 15	410	1422	49 4	236	237	238	1392	1470	1407	987	1011	0 98	321	339	330	10536
23 19	412	1434	49 3	237	238	239	1407	1479	1419	1002	1026	0 98	324	345	333	10602
23 26	409	1446	49 5	235	237	237	1413	1497	1434	1002	1026	0 98	324	345	336	10716
23 30	407	1455	49 4	234	235	235	1422	1506	1440	1002	1026	0 98	321	345	333	10782
23 34	408	1458	49 6	234	236	236	1425	1509	1443	1005	1029	0 98	324	348	336	10851
23 41	409	1410	49 9	235	236	237	1383	1455	1392	975	999	0 98	315	336	324	10980
23 45	410	1443	50 0	236	237	238	1419	1488	1425	1002	1026	0 98	324	345	333	11046
23 49	407	1443	50 0	234	236	236	1410	1494	1428	996	1017	0.98	321	345	333	11112
23 56	408	1320	50 3	235	236	236	1290	1365	1302	915	933	0 98	296	315	306	11208
00 00	408	1398	50 5	234	236	236	1368	1449	1383	969	987	0 98	312	336	324	11274
00 04	408	1410	50 5	235	236	236	1380	1461	1395	978	996	0.98	315	339	324	11337
00 11	410	1413	50.6	235	237	237	1380	1464	1395	984	1002	0 98	318	339	327	11454
00 15	411	1398	50 6	236	238	238	1365	1446	1377	972	993	0 98	315	336	324	11517
00 19	409	1452	50 6	235	236	237	1422	1509	1434	1011	1029	0 98	327	348	336	11586
00 26	409	1419	50 7	235	237	237	1386	1470	1404	984	1005	0 98	318	339	327	11703

Appendix - 3/7 contd..

DATE : 13th, June ' 97

TIME	V	I	Hz	V(R)	V(Y)	V(B)	I(R)	I(Y)	I(B)	kW	kVA	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh
00 30	410	1398	50.6	236	238	238	1368	1446	1380	975	993	0 98	315	336	324	11769
00 34	408	1395	50.6	235	236	236	1356	1452	1377	969	987	0 98	312	336	321	11832
00.41	409	1428	50 7	235	237	237	1392	1485	1410	993	1011	0 98	318	345	330	11961
00 45	409	1410	50.6	235	237	237	1380	1458	1392	978	999	0.98	315	336	327	12027
00 49	409	1407	50 5	235	237	236	1368	1467	1392	978	996	0.98	312	339	327	12093
00 56	411	1407	50 4	236	237	238	1374	1455	1392	981	1002	0.98	318	336	327	12192
01 00	412	1416	50 5	237	238	239	1383	1461	1404	990	1011	0 98	318	342	330	12258
01.04	407	1440	50 4	234	235	236	1407	1488	1425	996	1014	0 98	321	342	333	12324
01 11	406	1425	50 5	233	235	235	1398	1476	1404	981	1002	0 98	318	339	327	12441
01.15	405	1440	50 5	233	234	234	1413	1488	1422	990	1011	0 98	321	342	330	12507
01 19	404	1446	50 5	233	234	234	1419	1497	1422	993	1011	0 98	321	345	330	12573
01 26	406	1455	50 6	234	235	235	1425	1509	1428	1002	1023	0 98	324	348	330	12687
01 30	405	1434	50 5	233	235	234	1410	1482	1413	987	1008	0 98	318	342	327	12756
01.34	406	1449	50 4	233	235	235	1422	1497	1428	996	1020	0 98	321	345	333	12822
01.41	405	1431	50 5	233	234	234	1401	1482	1413	984	1005	0 98	318	339	327	12951
01 45	404	1434	50 6	232	234	234	1404	1488	1416	984	1005	0 98	318	342	327	13017
01 49	406	1425	50 7	233	235	235	1392	1482	1404	981	1002	0 98	315	339	327	13083
01 56	404	1449	50 7	232	234	234	1440	1494	1425	996	1017	0 98	324	342	330	13182
02 00	407	1431	50 8	234	235	236	1404	1473	1419	990	1011	0 98	321	339	330	13251
02 04	407	1422	50 8	234	235	236	1392	1473	1404	984	1002	0 98	318	339	327	13317
02 11	406	1449	50 7	233	235	235	1416	1497	1431	999	1017	0 98	324	342	333	13434
02 15	407	1458	50 6	234	235	236	1428	1503	1446	1005	1026	0 98	324	345	336	13500
02 19	406	1464	50 7	233	235	235	1434	1509	1449	1008	1029	0 98	324	348	336	13566
02 26	404	1464	50 7	232	233	234	1437	1509	1446	1005	1023	0 98	324	345	333	13683
02 30	404	1428	50 7	232	234	234	1401	1476	1407	981	999	0 98	318	339	324	13752
02 34	405	1488	50 9	233	235	235	1461	1539	1467	1026	1047	0 98	333	354	339	13818
02 41	405	1458	50 8	233	234	234	1434	1503	1437	1002	1023	0 98	327	345	333	13950
02 45	405	1449	50 5	233	234	234	1425	1494	1428	996	1014	0 98	324	342	330	14016
02 49	407	1443	50 6	234	235	235	1413	1494	1425	996	1017	0 98	321	345	330	14082
02 56	404	1452	50 5	232	234	234	1419	1512	1431	999	1017	0 98	321	345	330	14181
03 00	404	1458	50 5	233	234	234	1428	1512	1434	1002	1020	0 98	324	345	333	14247

Appendix - 3/7 contd..

TIME	V	I	Hz	V(R)	V(Y)	V(B)	I(R)	I(Y)	I(B)	kW	kVA	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh
03 04	406	1431	50 6	233	235	235	1407	1479	1410	987	1005	0 98	321	342	327	14316
03 11	406	1428	50 6	233	235	235	1398	1485	1404	984	1005	0 98	318	342	324	14430
03 15	406	1431	50 6	233	235	235	1401	1491	1407	987	1005	0 98	318	342	327	14496
03 19	406	1428	50 6	234	235	235	1401	1482	1404	984	1005	0 98	318	339	327	14562
03 26	407	1440	50 7	234	236	236	1413	1491	1422	996	1017	0 98	321	345	330	14679
03 30	408	1404	50 6	234	236	236	1374	1458	1386	975	993	0 98	315	336	324	14745
03 34	408	1422	50 6	235	236	236	1395	1470	1404	990	1005	0 98	318	342	330	14808
03 41	406	1461	50 6	233	235	235	1428	1512	1443	1008	1029	0.98	324	348	336	14940
03 45	405	1455	50 6	232	234	234	1425	1506	1434	999	1020	0 98	324	345	333	15006
03 49	407	1446	50 5	234	235	235	1419	1488	1428	1002	1017	0.98	324	342	333	15072
03 56	407	1443	50 5	234	235	235	1416	1485	1428	996	1017	0 98	321	342	333	15171
04 00	407	1434	50 5	234	235	235	1404	1485	1416	990	1008	0 98	318	342	330	15237
04 04	407	1452	50 6	234	235	235	1422	1503	1434	1005	1023	0 98	324	345	333	15306
04 11	406	1464	50 7	233	235	235	1437	1515	1440	1011	1029	0.98	327	348	336	15423
04 15	407	1452	50 7	234	235	236	1416	1506	1434	1005	1023	0 98	324	348	333	15489
04 19	406	1437	50 6	234	235	235	1404	1491	1416	993	1011	0 98	321	345	330	15555
04 26	406	1452	50 6	233	235	235	1425	1500	1431	999	1020	0 98	324	345	333	15672
04 30	405	1449	50 6	233	235	235	1425	1500	1428	999	1017	0 98	324	345	333	15738
04.34	404	1455	50 6	232	234	234	1431	1506	1434	996	1017	0 98	324	342	330	15807
04 41	402	1464	50 5	231	233	233	1434	1509	1446	1002	1020	0.98	324	342	333	15936
04 45	401	1455	50 5	230	232	232	1422	1503	1437	990	1011	0 98	321	342	330	16005
04 49	402	1464	50 3	231	232	232	1428	1515	1449	996	1017	0.98	321	345	333	16071
04 56	403	1464	50 1	232	233	233	1428	1521	1449	1002	1023	0.98	321	345	333	16170
05 00	402	1527	50 3	231	232	232	1500	1578	1509	1041	1062	0 98	336	357	345	16239
05 04	400	1476	50 4	230	232	232	1440	1530	1455	1002	1023	0.98	321	348	333	16305
05 11	398	1485	50.2	229	230	230	1455	1542	1461	1002	1023	0 98	324	348	333	16425
05.15	398	1518	50 0	229	230	230	1488	1575	1491	1023	1044	0 98	330	354	339	16494
05.19	402	1506	49 8	231	233	232	1470	1566	1482	1026	1047	0.98	330	357	342	16560
05 26	402	1473	49 3	231	232	233	1443	1527	1449	1002	1023	0.98	324	345	333	16680
05 30	401	1467	49 1	231	232	232	1437	1518	1446	996	1020	0.98	324	342	330	16746
05 34	400	1467	49 0	230	231	231	1431	1524	1446	993	1014	0.98	318	342	330	16812

Appendix - 3/7 contd..

TIME	V	I	Hz	V(R)	V(Y)	V(B)	I(R)	I(Y)	I(B)	kW	kVA	Cos ϕ	kW(R)	kW(Y)	kW(B)	kWh
05 41	399	1455	48 6	230	231	231	1413	1518	1434	981	1005	0.98	315	342	327	16941
05 45	399	1446	48 6	230	231	231	1419	1494	1431	975	1002	0.98	315	336	327	17007
05.49	400	1440	48 5	230	232	231	1407	1491	1425	975	999	0.98	315	336	324	17070
05.56	400	1416	48 5	230	231	231	1383	1464	1404	957	981	0.98	309	330	318	17169
06.00	402	1410	48 8	231	233	232	1365	1464	1398	957	981	0 98	306	333	321	17232
06 04	405	1458	50 0	233	234	234	1425	1497	1452	1002	1023	0.98	324	342	336	17298
06.11	403	1494	50 1	231	233	233	1452	1542	1485	1020	1041	0.98	327	351	342	17415
06 15	404	1479	50 0	232	234	234	1440	1530	1473	1014	1035	0 98	324	348	339	17484
06 19	402	1491	49 9	231	232	232	1446	1542	1488	1017	1038	0 98	324	351	342	17550
06 26	402	1485	49 5	231	233	233	1440	1533	1485	1011	1035	0 98	324	348	342	17670
06 30	401	1473	49 3	231	232	232	1434	1521	1470	1002	1023	0.98	321	345	336	17736
06 34	401	1479	49 4	231	232	232	1443	1530	1470	1008	1029	0 98	324	348	336	17802
06 41	401	1455	49 2	231	232	232	1413	1506	1449	990	1011	0 98	318	342	333	17934
06 45	401	1431	49 0	231	232	232	1392	1479	1425	972	993	0 98	312	333	324	17997
06 49	400	1410	48 8	230	231	231	1374	1455	1401	954	975	0 98	306	330	318	18063
06 56	399	1410	48 7	230	231	231	1368	1452	1413	954	975	0.98	306	327	321	18159
07 00	399	1437	48 7	229	231	231	1401	1485	1434	975	993	0 98	312	333	327	18222
07 04	398	1410	48 8	229	230	230	1371	1458	1404	951	972	0 98	306	327	318	18285
07 11	396	1395	48 4	228	229	229	1359	1440	1386	933	954	0 98	300	321	312	18396
07 15	393	1401	48 2	226	228	227	1368	1443	1389	933	954	0 98	303	321	312	18459
07 19	398	1368	48 3	229	231	231	1332	1410	1359	921	942	0 98	297	318	309	18519
07 26	400	1368	48 3	230	231	231	1332	1416	1356	924	948	0 98	298	318	309	18630
07 30	399	1401	48 5	229	231	230	1368	1446	1395	948	969	0 98	306	327	318	18693
07 34	400	1383	48 5	230	232	231	1350	1422	1380	936	960	0 98	303	321	315	18756
07 41	401	1341	48 5	230	232	232	1308	1389	1332	912	930	0 98	293	312	306	18876
07 45	399	1374	48 5	230	231	230	1341	1428	1356	927	948	0 98	299	321	309	18939
07 49	399	1380	48 6	229	231	231	1341	1428	1368	933	954	0 98	300	321	312	19002
07 56	399	1404	48 6	229	231	231	1368	1452	1386	948	969	0 98	306	327	315	19095
08 00	400	1419	48 6	230	231	231	1386	1470	1404	960	981	0 98	309	330	321	19158

MCC INCOMING FEEDER LOADING PARAMETERS

Sl. No.	APPLICATION	CABLE			SINGLE PHASE PARAMETERS					CALCULATED 3ϕ PARAMETERS					CALCULATED DISTRIBUTION LOSS (kWh/pa)
		SIZE (Sq.mm)	No.OF RUNS	LENGTH (Meters)	VOLT	AMP	PF	kVA	kW	VOLT	AMP	PF	kVA	kW	
1	MCC - 1 Incoming	3 5CX240	2	67	229	43 4	0 98	9 46	9 02	397	94 3	0 99	63 5	58 9	923 7
					229	50 9	0 99	11 70	10 62						
2	MCC - 2 Incoming	3 5CX240	1	55	230	21 6	0 80	4 87	4 29	398	21 6	0 80	14 6	12.9	79.6
3	MCC - 3 Incoming	3 5CX240	3	220	233	65 6	0.73	15 25	10 69	404	193 7	0.77	134 9	101 3	8531 7
					233	64 3	0 81	14 96	11 88						
					233	63 8	0 77	14 74	11 19						
4	MCC - 4 Incoming	3 5CX240	2	240	231	78 3	0 76	18 11	15 14	401	145 2	0 77	99 9	84 1	7844 9
					232	66 9	0 77	15.19	12 89						
5	MCC - 5 Incoming	3 5CX300	4	100	228	68 1	0 98	15 50	15 23	395	271 5	0 97	198 2	182.9	4586 4
					228	68 1	0 97	16 97	15 27						
					228	67 5	0.97	16 80	15 22						
					228	67 8	0.97	16 80	15 23						
6	MCC - 6 Incoming	3.5CX300	4	105	228	92 1	0 85	21.00	18 24	395	388 7	0 85	264 7	227 1	9870.7
					228	91 7	0 85	20 50	17 75						
					228	93 2	0 84	21 25	18 06						
					228	111 7	0 85	25 47	21 65						
7	MCC - 7 Incoming	3 5CX400	1	30	232	99 7	1 00	22 50	22 50	402	99.7	1 00	67 5	67.5	585.0
8	MCC-9N Incoming	3 5CX240	1	70	230	30 4	0 68	6 97	4 66	398	30 4	0 68	20 9	14.0	200.6
9	MCC -10 Incoming	3.5CX240	2	240	230	93 6	0 88	21 40	19 40	398	180.1	0 89	126 6	116.0	12069 3
					230	86 5	0 89	20 80	19 26						

Note ·

(a) MCC - 4 Capacitor connected in concentration plant feeder switched off for shifting to new MCC. hence PF is low

(b) Sample evaluation is made and presented in Appendix - 3/8 a

(c) Techno-economics are presented in Appendix - 3/8 b

COMPUTATION OF DISTRIBUTION LOSSES IN LT SYSTEM NETWORK AND POWER FACTOR IMPROVEMENT

Feeder = MCC-6

Measured Power Parameters

Voltage (V)	Current (A)	Power Factor Cos ϕ	Apparent Power kVA	Active Power kW
395	388.7	0.85	264 7	227.1

Cable used : 3½ X 300 sqmm (Al)

Formula used for computation:

1. $L_1 = 3 \times I_1^2 \times \frac{R_c}{N_r} \times L_c \times LLF \times \frac{h_y}{1000}$

2. $I_2 = I_1 \times \frac{PF_1}{PF_2}$

3. $\Delta L_{kWh} = 3\,(I_1^2 - I_2^2) \times \frac{R_c}{N_r} \times L_c \times LLF \times \frac{h_y}{1000}$

4 $SAV_{Rs} = 3 \times [I_1^2 - (I_1 \times \frac{PF_1}{PF_2})^2] \times \frac{R_c}{N_r} \times LC \times LLF \times T_{kWh} \times \frac{h_y}{1000}$

5. $D_{sav} = D_{kVA} \times (1 - \frac{PF_1}{PF_2})$

6. $SAV_{Demand} = T_{kVA} \times D_{sav} \times 12$

7. $CAP_{kVAr} = L_{kW} \times (\tan\phi_1 - \tan\phi_2)$

8. $CAP_{cost} = CAP_{kVAr} \times Cost_{kVAr}$

9. $LLF = \frac{\sum I_x^2}{I^2_{max} \times 8760}$

10. % Reduction in current $= \frac{(I_1 - I_2)}{I_1} \times 100$

Appendix 3/8 a contd.

Where,

I_1	= Measured Total current, Amps	= 388.7 A
R_c	= Cable resistance, ohms/meter	= 1.22×10^{-4} Ω/m
N_r	= Number of runs of cable	= 4
L_c	= Cable length, m	= 105 m
LLF	= Loss Load Factor	= 0.85 (Assumed)
h_y	= Annual operating hours	= 8000 hrs
L_1	= kWh loss "as is" per year	
PF_1	= Measured power factor Cos (ϕ_1)	= 0.85
PF_2	= Improved Power factor Cos(ϕ_2)	= 0.98
ΔL_{kWh}	= Annual savings in kWh loss	
SAV_{Rs}	= Annual savings of kWh loss reduction (in Rs.)	
T_{kWh}	= Energy charge (Rs./kWh) of the tariff	= Rs. 1 65 / kWh
D_{sav}	= Reduction in kVA	
D_{kVA}	= Measured kVA	= 264.7 kVA
SAV_{demand}	= Annual savings through reduction in kVA demand (in Rs)	
T_{kVA}	= Demand charge of the tariff per month	= Rs. 70 / kVA
CAP_{kVAr}	= Capacitor compensation to achieve kVA reduction	
L_{kW}	= Measured load, kW	= 227 1 kW
$Cost_{kVAr}$	= Cost of capacitor per kVAr	= Rs. 300/-
I_x	= Load current	
I_{max}	= Peak load current	

Calculations :

Using the above equations and the measured values, savings in the feeder has been computed and is given below:

1.	kWh loss "as is" per annum (L_1)	= 9870 7 kWh
2.	New current (I_2)	= 337.14 A
3.	% reduction in current	= 13 3
4.	Reactive compensation (CAP_{kVAr})	= 95 kVAr
5.	Total cost of capacitor (CAP_{cost}) or Cost of installation	= Rs. 28,500/-
6.	kWh loss reduction per annum (ΔL_{kWh})	= 2445.1 kWh
7.	Demand savings (D_{sav})	= 35 kVA
8.	Annual savings in kWh loss reduction (SAV_{Rs})	= Rs 4034.00
9.	Annual savings through reduction demand (SAV_{demand})	= Rs 29,400 00
10.	Total annual savings (8+9)	= Rs 33,434 00
11.	Simple payback period	= $\frac{\text{Cost of Installation}}{\text{Total annual savings}}$
		= 0 85 years

Note : LLF is assumed to be 0 85

Similar calculation has been carried out for other feeders and the techno-economics, is represented in Appendix - 3/8b For feeder MCC-3,4 and 10 capacitor banks are relocated from main PCC panel to respective MCC panel (Refer section 3.2 G). Hence, further annual demand reduction cannot be accounted.

APPENDIX - 3/8 b

COMPUTATION OF SAVINGS IN MCC INCOMING FEEDERS

Sl. No.	APPLICATION	PRESENT Cos ϕ	REQD. Cos ϕ	PRESENT DIST. LOSS (kWh/annum)	NEW DIST. LOSS (kWh/annum)	% REDUCTION IN CURRENT	CAPACITY REQUIRED IN kVAr	SAVING IN DIST. LOSSES kWh/pa	ANNUAL SAVING IN Rs.	COST OF INSTAL-ATION	SIMPLE PAY BACK PERIOD (Year)
1	MCC - 3 Incoming	0.77	0.97	8531.7	5376.1	20.6	59	3155.5	5427.5	NIL	Immediate
2	MCC - 4 Incoming	0.77	0.94	7844.9	5264.0	18.1	39	2580.9	4439.1	NIL	Immediate
3	MCC - 6 Incoming	0.85	0.98	9870.7	7425.6	13.3	95	2445.1	33434.0	28500	0.85
4	MCC -10 Incoming	0.89	0.98	12069.3	9954.3	9.2	36	2115.0	3637.8	NIL	Immediate
				TOTAL				10296.5	46938	28500	0.6

L.T. MOTOR LOADING PARAMETERS

MCC - 1

SL. No.	APPLICATION CONNECTED EQPT.	MOTOR RATED kW	MEASURED 1- Ph. PARAMETERS					CALCULATED 3 - Ph PARAMETERS			% LOAD--ING	REMARKS
			Volts V	Amps A	Pf. Cosϕ	kVA	kW	V	kVA	kW		
1	Sludge Pump - B	2.2	235	2 7	0 27	0.60	0 15	407	1.8	0 4	20.3	
2	Sludge Pump - C	2 2	235	3 2	0 80	0.87	0 64	407	2 6	1 9	87 0	
3	Sludge Pump - A	2 2	Standby for Sludge Pump - B & C									
4	Raw water Pump - C	7 5	233	9 9	0.87	2 30	2 10	404	6 9	6 3	84 0	
5	Clarifier rack arm	2 2	233	2 3	0 21	0 53	0.98	404	1 6	2 9	133 6	
6	RBT Pump	2 2	232	3 0	0.73	0.70	0 41	402	2 1	1 2	55.6	
7	Hydrogen Compressor-C CW Pump	15 0	226	21.0	0 90	5.01	4.40	391	15 0	13 2	88 0	
8	Reactor tank agitator - B	5 5	233	4 1	0 36	1.04	0.27	404	3.1	0.8	14.7	
9	Reactor tank agitator - A	5 5	Standby for Reactor tank agitator - B									
10	Saturated Brine Pump - A	15 0	208	13 2	0.84	2.76	1 87	360	8.3	5 6	37 4	Variable speed drive is provided
11	Saturated Brine Pump - B	15 0	Standby for Saturated Brine Pump - A									
12	CBT Pump - A	18.5	Standby for CBT Pump - B									
13	CBT Pump - B	18 5	234	22.3	0 91	5 27	4 83	405	15 8	14.5	78 3	
14	Brine bore well Pump	9 3	239	13.0	0.57	3.16	1.75	414	9.5	5 3	56.5	

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L.T. MOTOR LOADING PARAMETERS

CELL HOUSE - I

MCC - 2 & MCC - 3

SL. No.	APPLICATION CONNECTED EQPT.	MOTOR RATED kW	MEASURED 1- Ph. PARAMETERS					CALCULATED 3 - Ph PARAMETERS			% LOAD--ING	REMARKS
			Volts V	Amps A	Pf. Cosϕ	kVA	kW	V	kVA	kW		
	MCC - 2											
1	DM water Pump - A	2.2	234	4 0	0 76	0 94	0.70	405	2.8	2.1	95 7	
2	Rect - I transformer oil Pump	3 2	238	5 4	0 81	1 29	1 02	412	3 9	3.1	95 3	
3	Cooling water return Pump - A	11.0	234	16 4	0 98	3.45	3 58	405	10.4	10 7	97 6	
	MCC - 3											
1	Depleted Brine Pump - B	7.5	233	9 3	0 80	2 20	1.64	404	6 6	4 9	65.6	
2	Depleted Brine Pump - A	7 5	Standby for Depleted Brine Pump - B									
3	Sodium Hypo circulation Pump - A	2.2	233	2 8	0 65	0 65	0 42	404	1 9	1 3	57 4	
4	Sodium Hypo circulation Pump - B	2 2	Standby for Sodium Hypo circulation Pump - A									
5	Gaurd Tower Pump	2 2	232	2.0	0.38	0 45	0.20	402	1.4	0 6	27.8	
6	Main DM water Pump - B	3 7	232	5 0	0 78	1 16	0.88	402	3 5	2 6	71.4	
7	Caustic Product Pump - E	3 7	233	7 3	0 81	1 69	1 34	404	5.1	4.0	108 6	
8	Caustic Product Pump - D	3 7	Started as per process demand									
9	Caustic Product Pump - C	3 7	Started as per process demand									
10	Air Compressor - A	22.0	232	18 5	0 98	4 39	4 38	402	13.2	13 1	59 7	4 Min loading
			232	8.5	0.85	1 96	1 43	402	5 9	4.3	19 5	50 Sec unloading
11	Air Compressor - B	22 0	Standby for Air Compressor - A & C									
12	Dechlorinated Brine Pump - A	7 5	233	8 4	0 91	1 96	1.75	404	5 9	5.3	70 0	
13	Dechlorinated Brine Pump - B		Standby for Dechlorinated Brine Pump - A									
14	Caustic circulation Pump - B	5 5	233	8 9	0 90	2 12	1 85	404	6 4	5 6	100 9	
15	Caustic circulation Pump - A	5 5	Standby for Caustic circulation Pump - B									
16	Air Blower - B	5 5	232	4 2	0 46	0 98	0 44	402	2 9	1 3	24 1	

L.T. MOTOR LOADING PARAMETERS

MCC - 3 (Contd.) & MCC - 4

SL. No.	APPLICATION CONNECTED EQPT.	MOTOR RATED kW	MEASURED 1- Ph. PARAMETERS					CALCULATED 3 - Ph PARAMETERS			% LOAD--ING	REMARKS
			Volts V	Amps A	Pf. Cosϕ	kVA	kW	V	kVA	kW		
17	Air Blower - A	5 5	Standby for Air Blower - B									
18	Sodium Hypo Blower - A	15 0	Standby for Sodium Hypo Blower - B									
19	Sodium Hypo Blower - B	15 0	233	6 4	0 79	1.56	1 19	404	4.7	3 6	23 8	
20	Sodium Hypo circulation Pump - C	2 2	235	4 0	0 75	0.95	0 65	407	2 8	2.0	88 8	
21	Caustic dilution Pump	2 2	234	2 2	0 45	0 52	0 27	405	1.6	0 8	36 8	
22	Raw water distribution Pump - A	7 5	Standby for Raw water distribution Pump - B									
23	Raw water distribution Pump - B	3 7	231	5 7	0 87	1 23	1 05	400	3 7	3 1	84 8	
24	Sec. Brine Pump - A	5 5	231	5 7	0 87	1.33	1 12	400	4 0	3 4	61 3	
25	Sec Brine Pump - B	5 5	Standby for Sec Brine Pump - B									
	MCC - 4											
1	Hydrogen Blower	9 3	230	12 1	0 56	2 80	1 38	398	8 4	4 1	44 5	
2	Chlorine Blower - A	15.0	226	15 1	0 93	3 43	3.11	391	10 3	9 3	62 2	
3	Chlorine Blower - B	15 0	Standby for Chlorine Blower - A									
4	Caustic Product Pump - A (storage)	7 5	231	8 1	0 91	1 87	1 67	400	5.6	5 0	66 8	
5	48 % NaOH circulation Pump	2 2	231	3 8	0 80	0 89	0 70	400	2.7	2 1	95 5	
6	Air Compressor - C	22 0	223	39 0	0 55	8 94	4 76	386	26 8	14 3	64 9	
7	Cooling Tower Fan - A	18 5	228	21.0	0.96	4.86	4 50	395	14 6	13 5	73 0	Variable speed drive is provided
8	Cooling Tower Fan - B	18 5	231	25 5	0 86	5.94	3 40	400	17 8	10 2	55 1	Variable speed drive is provided
9	Well water Pump	9 3	228	13 0	0 72	2.98	2 00	395	8 9	6 0	64.5	

L.T. MOTOR LOADING PARAMETERS

MCC - 5, MCC - 6 & MCC - 7

SL. No.	APPLICATION CONNECTED EQPT.	MOTOR RATED kW	MEASURED 1- Ph. PARAMETERS					CALCULATED 3 - Ph PARAMETERS			% LOAD--ING	REMARKS
			Volts V	Amps A	Pf. Cosϕ	kVA	kW	V	kVA	kW		
	MCC - 5											
1	Freon Compressor - A	110.0	229	136.0	0.86	31 40	26.50	397	94.2	79 5	72 3	
2	Chlorine Compressor - A	90.0	230	122 7	0 91	28.50	26 00	398	85.5	78 0	86 7	
3	Chilled water Compressor - B	110.0	229	126 0	0 95	23.80	22 60	397	71.4	67.8	61 6	
4	Chilled water Pump - A	18 5	235	24 9	0 89	6.13	5 48	407	18 4	16.4	88 9	
6	78 % H_2SO_4 Pump - A	5 5	Standby for 78 % H2SO4 Pump - B									
7	Drying tower circlculation Pump - A	2 2	Standby for Drying tower circlculation Pump - B									
8	Cooling tower Pump - A	18 5	Standby for Cooling tower Pump - B									
	MCC - 6											
1	Freon Compressor - B	110.0	Standby for Freon Compressor - A									
2	Chlorine Compressor - B	90 0	Standby for Chlorine Compressor - A & C									
3	Chlorine Compressor - C	90 0	226	127 8	0 89	28 80	25.20	391	86.4	75 6	84 0	
4	Chilled water Pump - B	18 5	233	25 1	0.89	5.88	5 08	404	17 6	15.2	82 4	
6	78 % H_2SO_4 Pump - B	5 5	232	6 0	0.86	1 38	1 19	402	4 1	3 6	64 9	
7	Drying tower circlculation Pump - A	2.2	235	4 1	0 84	0 95	0 78	407	2 9	2.3	106 1	
8	Cooling tower Pump - B	18 5	232	29 2	0 85	6 87	5 61	402	20.6	16 8	91 0	
9	Cooling tower Fan	15 0	233	13 3	0 77	3.10	2 39	404	9 3	7 2	47 7	Variable speed drive is provided
	MCC - 7											
1	Hydrogen Compressor - A	80 0	232	71 2	0 77	16.40	11 59	402	49 2	34 8	43 5	
2	Hydrogen Compressor - B	45 0	230	51 4	0 90	11 67	10 32	398	35 0	31 0	68 8	
3	Hydrogen Compressor - C	80 0	233	88 0	0 88	20.50	17 35	404	61 5	52 1	65 1	Soft Starter is provided

L.T. MOTOR LOADING PARAMETERS

CELL HOUSE - I I

MCC - 9N & 9E

SL. No.	APPLICATION CONNECTED EQPT.	MOTOR RATED kW	MEASURED 1- Ph. PARAMETERS					CALCULATED 3 - Ph PARAMETERS			% LOAD--ING	REMARKS
			Volts V	Amps A	Pf. Cosϕ	kVA	kW	V	kVA	kW		
1	Lean Brine Pump - A	3 7	232	5 2	0.86	1.30	1 06	402	3 9	3.2	85 9	
2	Lean Brine Pump - B	2 2	Standby for Lean Brine Pump - A									
3	Vacuum Pump - A	5 5	229	9 8	0 74	2.22	1 55	397	6 7	4 7	84 5	
4	Vacuum Pump - B	5.5	Standby for Vacuum Pump - A									
5	Pure Brine Pump - A	7 5	228	7 2	0.92	1 66	1 48	395	5 0	4 4	59 2	
6	Pure Brine Pump - B	7 5	Standby for Pure Brine Pump - A									
7	Catholyte Pump - A	11 0	229	18 8	0 92	4.30	3.91	397	12 9	11.7	106 6	Variable speed drive is provided
8	Catholyte Pump - B	11 0	Standby for Catholyte Pump - A									
9	Polished Brine Pump - A	18 5	Standby for Polished Brine Pump - B									
10	Polished Brine Pump - B	18 5	230	21 1	0 89	4 85	4 29	398	14.6	12 9	69 6	
11	Product NaOH transfer Pump - A	7.5	235	8 3	0.74	1 93	1.36	407	5 8	4 1	54 4	
12	Product NaOH transfer Pump - B	7 5	Standby for NaOH transfer Pump - A									
13	Z1PMU002 Pump	2.2	232	4 5	0 64	1 03	0 66	402	3 1	2 0	90 0	

L.T. MOTOR LOADING PARAMETERS

MCC - 10 & MCC - 12

SL. No.	APPLICATION CONNECTED EQPT.	MOTOR RATED kW	MEASURED 1-Ph. PARAMETERS					CALCULATED 3-Ph PARAMETERS			% LOAD-ING	REMARKS
			Volts V	Amps A	Pf. Cosϕ	kVA	kW	V	kVA	kW		
	MCC - 10											
1	Cooling water Pump - B	90.0	229	114.3	0.86	26.10	22.20	397	78.3	66.6	74.0	
2	Thermic fluid Pump	37.0	227	39.4	0.91	8.96	8.26	393	26.9	24.8	67.0	
3	NaOH intermediate Pump (37%)	3.7	227	6.1	0.88	1.40	1.20	393	4.2	3.6	97.5	
4	Vacuum Pump	11.0	227	13.1	0.85	2.96	2.59	393	8.9	7.8	70.6	
5	Saccike Combustion Blower	5.5	223	9.3	0.87	2.08	1.67	386	6.2	5.0	91.1	
6	Boiler Combustion blower	2.2	227	3.8	0.76	0.94	0.64	393	2.8	1.9	86.9	
7	Oil feed Pump - A	2.2	227	3.4	0.50	0.79	0.47	393	2.4	1.4	64.2	
8	Water feed Pump - A	3.7	228	6.4	0.79	1.46	1.09	395	4.4	3.3	88.5	
9	Filtered water Pump - A	5.5	229	7.3	0.81	1.68	1.45	397	5.0	4.4	79.1	
10	RO Plant (New) H.P. Pump	15.0	224	21.7	0.93	4.85	4.54	388	14.6	13.6	90.8	
11	Intake feed Pump (RO)	2.2	226	2.3	0.61	0.57	0.37	391	1.7	1.1	49.9	
	MCC - 12											
1	Clear Brine Pump - B	5.5	230	7.6	0.71	1.83	1.22	398	5.5	3.7	66.5	
2	Slurry tank agitator	5.5	231	5.6	0.26	1.05	0.18	400	3.2	0.5	10.0	
3	Product slurry Pump	3.7	229	5.7	0.84	1.30	1.07	397	3.9	3.2	86.8	
4	Slurry tank agitator	5.5	231	4.3	0.26	0.98	0.21	400	2.9	0.6	11.3	
5	Crude Slurry Pump	3.7	231	4.6	0.82	1.07	0.85	400	3.2	2.6	69.2	

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APPENDIX - 4/2
Sht 1 of 2

REPLACEMENT OF STANDARD MOTORS BY HIGH EFFICIENCY MOTOR

Application : Hydrogen Compressor - A

Rated kW	= 80 kW
Measured kW	= 35.77 kW
Full load efficiency (Rated), η -	= 0.82

Derived data

Full load power $= \dfrac{\text{Rated kW}}{\text{Rated } \eta_{FL}}$

$= 97.56$ kW

Demand factor (D.F) $= \dfrac{\text{Measured kW}}{\text{Full load power}}$

$= 0.37$ kW

Operating efficiency $= (1 - \dfrac{(1-\eta(k_1 + (DF)^2 \times k_2)}{DF} x)100$

η = efficiency of motor
DF = demand factor
k_1 & k_2 are constants

Appendix - 4/2 contd..
Sht 2 of 2

$$= \left(1 - \frac{(1-0\ 82)\ (0.38+(0\ 37)^2 \times 0\ 62}{0.37}\right) \times 100$$

= 77 25 %

Operating losses	= (1-η) x measured power
	= (1 - 0.7725) x 35 77
	= 8 14 kW

It is proposed to replace this motor by a high efficiency motor having a rated capacity of 45 kW

Rated full load efficiency	= 93%
Operating efficiency of the motor with the present loading (using the same formulae)	= 93 19%
Operating losses	= (1 - 0 9319) x 35 77
	= 2 43 kW
Reduction in losses	= 8 14 - 2 43 kW
	= 5 70 kW
Operating hours	= 4500/annum
Annual energy savings	= 25,659 kWh
Annual cost savings	= Rs 44,134 @ Rs 1 72/ kWh
Cost of implementation	= Rs 72,386/-
Simple payback period	= 1.64 years

Similar calculation for sizing of motors through computation has been carried out Appendix - 4/2a represents the techno-economics for replacement of ordinary motors by high efficiency motors and sizing.

USE OF ENERGY EFFICIENT MOTORS

SL. No.	APPLICATION	PRESENT DRIVE kW	MEAS-URED kW	PROPOSED HIGH EFF. MOTOR kW	OPERT. EFFIC. WITH NEW DRIVE	ANNUAL OPERT. HRS	SAVINGS IN kW	COST SAVINGS Rs	INST. COST	PAY BACK PERIOD
	MCC 1									
1	Brine bore well Pump	9 3	5 25	9 3	0 88	8000	2968	5105	14960	2.93
2	Saturated Brine Pump	15 0	5 58	15.0	0 90	4500	3114	5356	24129	4.50
	MCC 3									
1	Depleted Brine Pump	7 5	4 92	7 5	0 88	4500	1445	2485	12064	4.86
2	caustic Produt Pump - E	5 5	4 02	5.5	0 88	4500	1126	1937	8847	4.57
3	Caustic circulation Pump - B	5 5	5 55	5 5	0 88	4500	1438	2474	8847	3 58
5	Sec Brine Pump - A	5 5	3.37	5 5	0.88	4500	1024	1761	8847	5 02
	MCC 4									
2	Chlorine Blower - A	15 0	9 66	15 0	0 90	4500	3780	6502	24129	3.71
3	Air Compressor - C	22 0	14 28	22 0	0 91	3000	4158	7151	35389	4 95
4	Cooling tower fan - A	18 5	13 50	18 5	0 91	8500	10618	18263	29759	1 63
5	Cooling tower fan - B	18 5	10 20	18 5	0 91	8500	9154	15745	29759	1 89
6	Cooling tower fan - C	18 5	11 78	18 5	0 91	8500	9804	16863	29759	1 76
7	Thermic fluid Pump	37 0	17 46	37 0	0 93	5000	11730	20175	59517	2.95
9	Vacuum Pump	11 0	7 70	11 0	0 89	5000	2835	4876	17694	3.63
10	Saccke Blower	5 5	5 01	5 5	0 88	5000	1463	2517	8847	3 52
	MCC 6									
1	Cooling water Pump - B	18 5	16 83	18 5	0 90	4500	5890	10130	29759	2 94
	MCC 7									
1	Hydrogen Compressor - A	80 0	35 77	45 0	0.93	4500	25659	44134	72386	1.64
	MCC 9E									
1	Lean Brine Pump - A	5 5	3 18	5 5	0 88	4500	997	1716	8847	5 16
	MCC 10									
1	Filtered water Pump - A	5 5	4 00	5 5	0 88	4500	1123	1931	8847	4.58
4	Boiler oil feed Pump - A	5 5	3 27	5 5	0 88	5000	1122	1931	8847	4.58
	MCC 12									
1	Clear Brine Pump - B	5 5	3 66	5 5	0 88	4500	1067	1836	8847	4 82
	TOTAL						100517	172889	450080	2.60

APPENDIX - 4/3

L .T. MOTORS RECOMMENDED FOR STAR MODE OF OPERATION

SL. No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED kW	FULL LOAD EFFIC. η	FULL LOAD POWER	OPERT. LOSSES IN kW	SAVINGS IN LOSSES kW	OPERT. HOURS PER ANNUM	ANNUAL SAVINGS IN kWH	COST SAVINGS IN Rs	INSTA--LATION COST Rs	PAY BACK PERIOD
1	Sludge Pump - B	2 2	0 45	0 82	2 68	0 4	0 1	8000	714	1228 1	NIL	NIL
2	Gaurd tower Pump	2 2	0 61	0 82	2 68	0.6	0 1	8000	967	1663 2	NIL	NIL
3	Air Blower - B	5 5	1 33	0 82	6 71	1.3	0 3	8000	2115	3637 8	NIL	NIL
							TOTAL =		3796	6529.1	NIL	NIL

L .T. MOTORS RECOMMENDED FOR AUTO DELTA -STAR CONTROLLERS

SL. No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED kW	FULL LOAD EFFIC. η	FULL LOAD POWER	OPERT. LOSSES IN kW	SAVINGS IN LOSSES kW	OPERT. HOURS	ANNUAL SAVINGS kWH	COST SAVINGS Rs	INSTA--LATION COST Rs	PAY BACK PERIOD
1	Reactor tank Agitator	5 5	0 81	0 82	6 71	0 8	0 2	8000	1291	2220.5	10000 0	4 50
2	Slurry tank Agitator	5 5	0 55	0 82	6 71	0 5	0 1	8000	879	1511 9	10000 0	6 61
3	Slurry tank Agitator	5 5	0 62	0 82	6 71	0 6	0 1	8000	990	1702 8	10000 0	5 87
							TOTAL =		3160	5435.2	30000.0	5.52

APPENDIX - 4/4
Sht 1 of 2

REPLACEMENT OF ALUMINIUM BLADES WITH FRP BLADES

A. COOLING TOWER : 1 (Main)

No of fans	=	3
Power consumption of CT fan motor No A	=	13 5 kW
Power consumption of CT fan motor No B	=	10 2 kW
Power consumption of CT fan motor No C	=	11.78 kW
Total power consumption by all three CT fans in operation	=	35 48 kW
Assuming 25% reduction in power consumption of the fan (Manufacturers claim upto 40% savings by replacing with FRP blades by our earlier experience)	=	35 48 x 0 25
Energy savings per hour	=	8 87 kWh
Annual operating hours	=	8000 hours
Annual energy savings	=	8 87 x 8000
	=	70960 kWh
Annual cost savings @ Rs 1 72/kWh	=	Rs 122051 20/-
Cost of implementation for 3 fan blades (@ Rs 82,000/- per fan system)	=	Rs.2,46,000/-
Simple payback period	=	2 02 years

B. COOLING TOWER NO : 2 (LIQCHLOR)

No of fans	=	1
Power consumption of CT fan motor	=	7 23 kW
Assuming 25% reduction in power consumption of the fan (Manufacturers claim upto 40% savings by replacing with FRP blades)	=	7.23 X 0 25
Energy savings per hour	=	1.81 kWh
Annual operating hours	=	8000 hours
Annual energy savings	=	14480 kWh
Annual cost savings @ Rs.1 72/kWh	=	Rs 24,905 60/-
Cost of implementation @ Rs 67,200/ fan	=	Rs.67,200/-
Simple payback period	=	2.69 years

APPENDIX - 5/1

CHARACTERISTICS OF HYTHERM OIL 500

Colour	:	Deep Yellow
Appearance	.	Clear
Viscosity at 30°C	.	153 RWS
Specific gravity	·	0 86 at 33 °C
Specific heat	.	100°C - 0 466 $\frac{Btu}{(lb\ ^\circ C)}$
		200 °C - 0 578 "
		500 °C - 0.688 "
Flash point	:	219 °C
Fire point	:	243°C
Boiling Point		371 °C
Thermal conductivity	:	100°F - 0.077 $\frac{Btu}{Ft^2\ h\ ^\circ F}$
		300 °F - 0 073 "
		500 °F - 0 068 "

APPENDIX - 5/2

PRODUCTION AND ENERGY CONSUMPTION DETAILS

Year/ Month	Production (48%)	F.Oil kL	Hydrogen. cum * 1000	R. Hrs
1993-94	6270.33	205.2	-	6501 36
1994-95	7168.11	216 96	415.86	7150 45
1995-96	7019.8	188.64	1771.77	7355.4
Apr'96	424	41 05	19.86	483
May	825	58 07	84 47	687
Jun	630	28.81	117.34	568
Jul	590	18 79	166.19	639
Aug	651.5	9.12	185.45	709
Sep	706	28.54	139.21	528 75
Oct	658 2	13.39	173.41	663 03
Nov	628.8	17 43	149.94	634 5
Dec	697.91	32.56	129.61	622 33
Jan 97	660	23 48	140 74	638
Feb	761 07	44 8	54.91	530
Mar	591	28	54 05	486
Apr	638	35.76	40 01	505
May	1361	26.63	249.5	705

FURNACE OIL CONSUMPTION

Year/ Month	Furnace Oil Qty/kL	Avg. Rate / kL. (Rs.)	For Conc. (kL)	For Boiler (kL)
1993-94	234 231	5477	205 231	29
1994-95	438	4899	217	221
1995-96	402	5014	189	213
1996-97	540	5641	344	196

APPENDIX - 5/3

OBSERVED PARAMETERS IN CONCENTRATION PLANT

A *Process Parameters*

Sp gravity	Inlet Caustic Lye			Outlet Caustic Lye	
	Flow m^3/h	Inlet temp °C	Inlet Conc. %	Inlet temp °C	Inlet Conc. %
1.35	4 5	76	33	42	48
1 35	4.5	78	33	43	48
1 35	4.5	76	33	42	48

B *Thermic Fluid Heater Parameters*

Duration Minutes	Thermic Fluid Outlet temp °C	Furnace Oil temp °C	Oil Pressure kg/cm^2g	Flue gas exit temp °C
9	221 to 212	102 to 119	5 8 to 3 0	245 to 261
4	213 to 217	109 to 111	3.0	243
8	210 to 219	111 to 103	5 8	241 to 265

APPENDIX - 5/4

ESTIMATION OF EFFICIENCY OF THERMIC FLUID HEATER

A *Basic Data*

i.	Fusion plant load	= 4.5 tons/h
ii	Oil flow rate	= 48 ltr/h
		= 43.2 kg/h
iii.	Specific weight of hydrogen	= 0.08935 kg/m^3
iv.	Hydrogen flow rate	= $\sqrt{18}$ X 50
		= 212 m^3/h = 18 9 kg/h
v.	Flue gas exit temperature	= 261 °C
vi.	Ambient temperature	= 34 °C
vii.	Measured % CO_2 in exit flue gases	= 4
viii.	Calorific value of furnace oil	= 10200 kcal/kg
ix	Calorific value of hydrogen	= 34042 kcal/kg
x.	Ultimate analysis of Furnace oil	= C 84% H 12% S 4%

Derived Data

i.	Total quantity of fuel	= 43.2 + 18.9 = 62 1 kg/h
	Percentage of oil flow rate	= 70%
	Percentage of hydrogen flow rate	= 30%

Appendix - 5/4 contd.

ii. 1 kg of Mixed Fuel

Carbon content	= 0.84 X 0.7 = 0.588 kg
Hydrogen content	= (0.12X0 7)+0.3=0 384 kg
Sulphur content	= 0 04 X 0.7 = 0.028 kg
1 kg of pure carbon requires	= 2 66 kg oxygen
1 kg of pure hydrogen requires	= 8 kg oxygen
1 kg of pure hydrogen requires	= 1 kg oxygen

Hence,

Carbon requires 2 66 X 0 588	= 1 56 kg oxygen
Hydrogen requires 0 384 X 8	= 3 072 kg oxygen
Sulphur requires 0 028 X 1	= 0 028 kg oxygen
	= 4.66 kg oxygen

Accompanying Nitrogen	= 15 60 kg
Hence,	
Quantity of theoretical air	= 20 3 kg/h of fuel
Total quantity of air required per kg of mixed fuel	= 1260 kg/h

Appendix - 5/4 contd.

iii. Production of combustion :

Basis 1 kg of mixed fuel

Product	kg of product generated	kg moles of product generated	%
Carbon di-oxide	$\frac{32X0\ 588}{12}$ =1.568	0 356	4 43
Water Vapour	9 X 0.384 = 3.456	0 192	24 40
Sulphur di-oxide	2 X 0 028 = 0.056	0 000875	0 111
Nitrogen	15 60	0 557	70 9
Total		0 7855	100

Hence theoretical % CO_2 = 4.43

percentage excess air $= \left[\frac{4\ 43}{4\ 0} - 1\right] X\ 100$

= (1.132 - 1)X100

= 13 2%

IV Heat loss due to sensible heat in flue gases =

$$\frac{100}{12 X 4\ 0} X \left[\frac{0.84}{100} + \frac{4}{267}\right] X30.6\ (261-34)\ X \frac{1}{4\ 18}$$

= 2960 kcal/kg

Calorific value of fuel = 0 3X34042+0 7X10200

= 10212 + 7140

= 17352 kcal/kg

% Heat loss $= \frac{2960}{17352} X\ 100$

= 17.0%

Appendix - 5/4 contd.

v. Estimation of equivalent oxygen in exit flue gas

Total quantity of air = 20.3 X 1.132

= 22.98 kg/kg fuel

Oxygen requirement = 5.285 kg

Nitrogen = 17 695 kg

Product	kg moles of product generated	%
Carbon di-oxide	0.0356	4.0
Water Vapour	0 192	21 8
Sulphuridi oxide	0 000875	0 1
Nitrogen	0 632	71 8
Excess Oxygen	$\frac{5\ 285\ -4\ 66}{32}$ = 0 0196	2.22
Total	0 880	100

vi Radiation and Convection Loss

Avg Surface temp , °C	Surface Area m^2	Heat loss kcal/h m^2	Total loss kcal/h
69	12.6	411	5179
67	11 0	408	4488
47	11.8	138	1628
50	11 8	173	2041
Total			13336

Heat loss due to convection and radiation= $(10 + \frac{69-34}{20}) \times (69-34)$

= 411.25 kcal/h

Percentage heat loss = $\frac{13336}{17352}$

= 1 23%

Total heat loss = 17 00 + 1.23

= 18.23

Efficiency = 10 - 18 23

= 81.77%

APPENDIX - 5/5

HYDROGEN GENERATION AND CONSUMPTION PATTERN

Month	H_2 prod. X 1000 m^3	Consumption X 1000^3			
		TFH	HBP	HCL	Vent
Apr'96	384	20	125	61	178
May	417	84	136	66	131
Jun	429	117	129	65	118
Jul	452	166	125	62	99
Aug	474	185	130	62	97
Sep	431	139	125	70	97
Oct	456	173	142	55	86
Nov	456	150	131	56	119
Dec	427	130	136	53	108
Jan'97	458	141	135	62	120
Feb	305	55	125	32	93
Mar	335	54	115	71	95
Total	**5024**	**1414**	**1554**	**715**	**1341**
	100%	**28%**	**31%**	**14%**	**27%**

APPENDIX - 6/1

OBSERVATIONS ON CHLORINE COMPRESSORS

Time	Compressor B - Plant - I			Compressor C - Plant - II		
	Inlet temp °C	Outlet temp °C	Delivery pressure kg/cm^2	Inlet temp °C	Outlet temp. °C	Delivery pressure kg/cm^2
11 AM	26	37 5	3 5	29 5	40	3 6
12 Noon	26	37 5	3 5	30	39	3.6
2 PM	27	37 5	3 65	30	39	3 7
3 PM	27	36 5	3 55	30	39	3 65

Compressor	Plant	Suction pressure
B	I	900 to 1000 mmWc
C	II	250 mm Wc

Design specifications of chlorine compressors

Outlet pressure = 4 kg/cm^2

Flow = 550 m^3/h

RPM = 980

APPENDIX - 6/2

OBSERVATIONS ON FREON COMPRESSORS

Date : 15.06.97

Time	Compressor				Condenser			
	Current Amps	Suction pressure psi	Delivery pressure psi	Compr. No.	Inlet pressure kg/cm^2	Outlet pressure kg/cm^2	Water in temp.°C	Water Out temp °C
10 AM	150	34	217	A	1.8	0.8	31	-
	100	32	193	B				
12 Noon	150	35	230	A	1.8	0 8	33	-
	85	33	200	B				
2 PM	150	37	225	A	1.8	0 8	32	-
	90	35	207	B				
4 PM	150	37	230	A	1.8	0.8	32	-
	90	35	210	B				
6 PM	150	37	230	A	1 8	0.8	32	-
	90	35	210	B				
8 PM	155	37	225	A	1.8	0 8	32	-
	90	35	205	B				
10 PM	155	37	225	A	1.8	0 8	31	-
	90	35	105	B				
12 PM	155	35	222	A	1.8	0 8	31	-
	90	36	200	B				
2 AM	152	34	220	A	1.8	0 8	31	-
	90	36	196	B				
4 AM	152	36	218	A	1 8	0 8	30	-
	90	34	195	B				
6 AM	150	36	218	A	1.8	0 8	30	-
	90	34	193	B				
8 AM	150	35	215	A	1 8	0 8	31	-
	95	33	191	B				

Appendix - 6/2 contd.

Date 16 06 97

Time	Compressor				Condenser			
	Current Amps	Suction pressure psi	Delivery pressure psi	Compr No.	Inlet pressure kg/cm^2	Outlet pressure kg/cm^2	Water in temp °C	Water Out temp °C
10 AM	150	38	220	A	1 8	0 8	30	29
	90	35	195	B	1.9	0 8	33	-
11 AM	150	38	220	A	1 8	0 8	30	29
	95	35	195	B	1 8	0 8	33	-
12 Noon	160	38	220	A	1 8	0 8	30	29
	90	35	195	B	1 9	0 8	33	-
1 PM	146	34	225	A	1 8	0 8	30	29
	91	33	199	B	1 8	0 8	33	-
2 PM	146	30	220	A	1 8	0 8	30	29
	91	34	200	B	1.9	0 8	34	-
3 PM	155	37	225	A	1 6	0 8	31	29
	92	37	210	B	1 9	0.8	34	-
4 PM	155	38	220	A	1 6	0 8	31	29
	90	37	214	B	1.9	0 8	34	-

APPENDIX - 6/3

OBSERVATIONS ON LIQUEFACTION CONDENSER

Date 15 06 1997

Time	Chlorine temp °C	Chlorine pressure kg/cm^2
10 AM	- 11 5	3 28
12 Noon	- 11 2	3 25
2 PM	- 7 6	3 20
4 PM	- 7 9	3.15
6 PM	- 7 9	3 15
8 PM	- 7 2	3 30
10 PM	- 7 1	3 35
12 PM	- 8 2	3 30
2 AM	- 8 5	3 13
4 AM	- 8.6	3.10
6 AM	- 8 9	3 05
8 AM	- 12.8	3 29

Date . 16 06 1997

Time	Chlorine temp °C	Chlorine pressure kg/cm^2
10 AM	- 7.2	3 10
11 AM	- 5 8	3 09
12 Noon	- 5 9	3 09
1 PM	- 9 2	3 32
2 PM	- 7 6	3 35
3 PM	- 7 1	3 15
4 PM	- 7 4	3 15

APPENDIX - 7/1

OBSERVATIONS ON CHILLED WATER SYSTEM

A OBSERVED PARAMETERS

Date : 16 06 97

Time	Suc Pres psig	Disch pres psig	Current Amps	Condenser Pressure (kg/cm^2g) Inlet	Condenser Pressure (kg/cm^2g) Outlet	Condenser Temp , °C Inlet	Condenser Temp , °C Outlet	Chiller Pressure (kg/cm^2g) Inlet	Chiller Pressure (kg/cm^2g) Outlet	Chiller Temp , °C Inlet	Chiller Temp , °C Outlet
10 00	75	222	110/140	2 3	0 8	35 5	31	3 8	3 1	18	12 5
11 00	70	237	135	2 3	0 8	36 5	31 5	3 8	3 1	18	12 0
12 00	70	237	110/140	2 3	0 8	36 5	31 8	3 8	3 1	18	12.0
14 00	70	235	140	2 3	0 8	36 5	31 8	3 8	3 1	18	12 0
15 00	72 5	235	140	2 3	0 8	36 5	32 0	3 8	3 1	18	12 0

B CHILLER AND CONDENSER EFFECTIVENESS

Condenser Pres. drop kg/cm^2g	Condenser Temp., °C	Chiller Pres drop kg/cm^2g	Chiller Temp., °C	Remarks
1.5	4 5	0 7	6 5	Condenser
1.5	5	0 7	6	Pressure
1.5	4 7	0 7	6	Drop
1 5	4 7	0 7	6	is high
1.5	4 5	0.7	6	

teri

APPENDIX - 7/2

PERFORMANCE EVALUATION OF CHILLED WATER SYSTEM

A. *BASIC DATA*

I	Measured chilled water flow	= 75.0 m^3/h
		≈ 70 0 m^3/h
II	Average inlet chilled water temp	= 18 °C
iii.	Average outlet chilled water temp.	= 12.0 °C
iv	Power input to comp	= 67 8 kW
v.	Power input to chilled water pump	= 14 0 kW
*VI	Power input to cooling tower fan	= 3 64 kW
*vii.	Power input to cooling water pump	= 8 75 kW

* Power input taken proportionate to water consumption

B. *DERIVED DATA*

I.	Total chilled water generated	$= \frac{70X1000X(17\ 5-12)}{3000}$
	Diff. in temp. Is taken as 5.5°C as the exact chilled water inlet temp could not be measured (Slightly higher value obtained due to higher measured flow because of improper sampling print)	= 128 TR
II	Total power input	= 94 2 kW
III	Specific power consumption	= 0 75 kW/TR

APPENDIX - 7/3

CHILLED WATER - USER LOAD ASSESSMENT

A. *Observations on 98% acid circulation cooler*

Reference	Time	Acid Temp °C		Chilled Water Temp °C		
		Inlet	Outlet	Inlet	Outlet	Rise
Comp 'B' Plant-1	10 30	43	32 5	12.5	20	7.5
	11 30	43	31 5	12.5	19.5	7.0
	12.30	42	30.5	12.0	18	6.0
	14.00	42.5	30.5	12.0	18	6.0
	15 00	42 0	30 5	12.0	18	6.0
Average						**6.5**
Comp 'C' Plant -2	10.30	36 5	23.5	12.5	20	7.5
	11.30	36.5	23 5	12.0	18 5	6.5
	12 30	35 0	23	12 0	18	6 0
	14 00	35 5	23	12 0	18	6.0
	15.00	36 5	25 5	12 0	18	6 0
Average						**6.4**

Refrigeration load of plant - 1 cooler = 18.28X1000X6.5
= 40 TR

Refrigeration load of plant - 2 cooler = 18.28X1000X6.4
= 39 TR

Appendix - 7/3 contd.

B *Estimation of User load of 78% Sulphuric Acid Coolers*

		Plant - 1	Plant - 2
a)	Measured power input	= 2.334 kW	3 57 kW
b)	Specific gravity	= 1.7	1 7
c)	Pump discharge pressure	= 26 m	30
d)	Efficiency of pump	= 0 6	0.6
e)	Efficiency of motor	= 0.85	0 85
f)	Estimated flow	= 9 9 m^3/h	13 m^3/h
g)	Specific heat	= 0.47 kcal/kg,°C	0 47kcal/kg
h)	Difference in temp.	= 2 °C	2 °C
i)	Estimated TR	= $\frac{9\,9X1\,7X2X1000X0.47}{3000}$	$\frac{3X1\,7X2X1000X0\,47}{3000}$
		= 5 5 TR	8 TR

C *Estimated Chilled water load in Hypo plant*

i. *Sodium hypo refrigeration load*

a	Design flow	= 12 m^3/h
b	Specific heat	= 0 9 kcal/kg °C
c	Difference in temp. of hypo solution across HE	= 3 6 °C
d	Estimated heat loss	= 12 X 1000X0 9X3 6
		= 38880 kcal/h
		= $\frac{13}{0.9}$ TR
		= 14 TR

teri

Appendix - 7/3 contd.

ii. *Acid circulation refrigeration Load*

a	Estimated flow	= 5 m^3/h
b	Specific heat	= 0 91 kcal/kg
c	Difference in temp of hypo solution across HE	= 4.4 °C
d	Estimated heat loss	= $\frac{5 \text{ X } 1000\text{X}0\ 91\text{X}4\ 4}{3000}$
		= 7 TR

D *Estimated chilled water load in chlorine coolers*

i	Design heat load in cooler in plant-2	= 8 TR
ii	Design heat load in cooler plant-1	= 5 TR

		= 13 TR

E *Total chilled water load* = (A)+(B)+(C)(D)

= 79 + 13 5+21+13

= 127 TR

APPENDIX - 7/4

ENERGY SAVINGS BY REDUCING PRESSURE FOR CHILLED WATER PUMP

A *Hot Well Pump*

i	Measured actual flow	= 75 m^3/h
ii	Head requirement	= 12 M
iii	Theoretical power	= $\frac{75 \text{ X } 12 \text{X } 9\ 81}{3600}$
		= 2 45 kW
iv	Actual power	= $\frac{2\ 45}{(\eta_p)0\ 6\text{X}0.85(\eta_m)}$
		= 4.8 kW
		= 7 5 HP (Motor capacity)

B *Cold Well Pump*

I. Estimated water requirement

a	98% H_2SO_4 acid cooler (plant-1)	= 18 28 m^3/h
b	98% H_2SO_4 acid cooler (plant-2)	= 18 28 m^3/h
c	78% H_2SO_4 acid cooler (plant-2)	= 8 m^3/h
d	78% H_2SO_4 acid cooler (plant-1)	= 5 m^3/h

II	Head requirement	= 15 m
III.	Theoretical power	= $\frac{50 \text{ X } 15 \text{ X } 9\ 81}{3600}$
		= 2 04 kW
IV.	Actual power	= $\frac{2\ 04}{(\eta_p)0\ 6\text{X}0.85(\eta_m)}$
		= 4 0 kW
		≈ 7.5 HP(Motor capacity)

teri

Appendix - 7/4 contd.

C. *Cold Well Pump*

i	Estimated water requirement for sodium hypo, acid cooler in hypo and chlorine cooler 1 & 2	= 25 m^3/h
ii	Head requirement	= 20m
iii	Theoretical power	= $\frac{25 \times 20 \times 9.81}{3600}$
		= 1.4 kW
iv	Actual power	= $\frac{1.4}{(\eta_p) 0.6 \times 0.85 (\eta_m)}$
		= 2.7 kW
		≈ 5 HP(Motor capacity)

D *Total Savings*

i	Total power input required	= 4.8 + 4.0 + 2.7
		= 11.5 kW
ii.	Existing power input	= 14 kW
iii.	Energy Savings	= 14 - 11.5
		= 2.5 kW
iv	Annual energy saving	= 2.5X8000X1.72
		= Rs. 34,400/-
v	Estimated investment	
	2 pumps of 75m^3/h 12m head including motors	= Rs. 70,000/-
	2 pumps of 50m^3/h 15m head including motors	= Rs 70,000/-
	2 pumps of 25m^3/h 20m head including motors	= Rs 40,000/-
	Insulated tank	= Rs. 50,000
	Valves	= Rs. 10,000/-
	Total	= Rs. 2,40,000/-
vi	Simple payback period	= $\frac{240000}{34400}$
		= 7 years.

teri

APPENDIX - 7/5

ENERGY SAVINGS BY APPLICATION OF VAPOUR ABSORPTION REFRIGERATION MACHINE FOR CHILLED WATER MACHINE

Basis:

i Approximate heat load = 125 X 3000

(Taking efficiency of vapour absorption machine to be 80%) = 3,75,000 kcal/h

$$= \frac{3,75,000}{0.8}$$

= 4,68,750 kcal/h

ii Quantity of hydrogen required

$$= \frac{468750}{34042}$$

= 13.8 kg/h

$$= \frac{13.8}{0.08935}$$

= 154 m^3/h

iii Month-wise average hourly hydrogen vented out is as given below (Based on 648 hrs/month running time)

Month/Year	m^3/h
Apr'96	275
May	202
Jun	182
Jul	152
Aug	150
Sep	150
Oct	132
Nov	184
Dec	167
Jan'97	185
Feb	144
Mar	147

Appendix - 7/5 contd

It can be observed that almost for about 9 months, the excess hydrogen available is sufficient to meet the fuel requirement for chilled water load For about 3 months, dual fuel may have to be employed

iv	Power input to compressor	= 67 8 kW
v	Annual energy savings (Other auxiliaries are required as in vapour compression machine)	= 67 8 X 8000 = 5,42,400 kWh
vi	Cost of energy savings	= Rs. 9,32,900/-
vii.	Estimated Investment (Vapour absorption machine dual fuel burners etc ,)	= Rs 60,00,000
viii	Simple payback period	$= \frac{6000000}{932900}$ = 6.4 years

APPENDIX - 8/1

FREE AIR DELIVERY TEST DETAILS

A. FAD CALCULATION FORMULA

$$\text{FAD capacity in } m^3/min = \frac{A}{B} \times \frac{C}{F} \times \frac{D}{E}$$

Where m

A	=	Volume of air receiver + interconnecting pipeline in m^3
B	=	Time taken to fill receiver in minutes
C	=	Cut off or final air pressure in kg/cm^2
D	=	Compressed air exit temp In °K
E	=	Inlet air temp in °K
F	=	Atmospheric air pressure in kg/cm^2

B. AIR COMPRESSOR FREE AIR DELIVERY (FAD)- DETAILS

Sl No	Compressor	Rated FAD m^3/min	Air Receiver + piping capacity m^3	Air pressure kg/cm^2	Suction velocity m/min	Suction pipe area m^2	Time taken to fill receiver + piping (mins)	Actual FAD m^3/min
1	A	2 63	0 52	6 4	282	0 004	-	1 13
2	B	2 63	0 52	6 4	228	0 004	-	0 91
3	C	2 63	0 52	6 4	228	0 004	-	0 91
4	D	2 63	0 48	8 4	-	-	3 58	1 16
5	E	2 63	0 84	8 4	-	-	2 75	2 62

SAVINGS ACHIEVABLE BY IMPROVING COMPRESSOR FAD

The FAD of the compressors should atleast be 85% of their rated FAD The impact of FAD improvement on savings for the compressors is tabulated below

Sl No	Compr	FAD m³/hr			Actual power drawn kW	Sp Energy cons (SEC) kW/100m³/h			Annual operational hrs	% redn in Sec	Savings	
		Rated	Existing	Improved		Existing	Improved	Redn			Annual energy savings kWh	Annual value of savings Rs
1	A	157 8	67 8	134 1	13 4	19 8	9 9	9 9	8000	50	53600	92192
2	C	157 8	54 6	134 1	14 28	26 2	10 6	15 6	8000	59	67402	115931
3	D	157 8	69 4	134 1	14 19	20 4	10 6	9 8	4800	48	32694	56233
Total											**153696**	**264356**

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APPENDIX - 8/3

QUANTIFICATION OF COMPRESSED AIR LEAKAGE

Procedures

With all air operated equipment shut off, run the compressor until the system reaches full set pressure and the compressor unloads, note the time Due to air leaks the system pressure will fall, and the compressor will come on load again, note the time The period for which the compressor is 'on load' and 'off load' should be recorded at least four times to give a mean value of each

Let T minutes	= Time on load
Let t minutes	= Time off load
Let Q	= Actual free air delivery capacity of compressor in m^3/hr
Let L	= Total system leakage in m^3/hr
L	$= \frac{Q \times T}{(T + t)} \; m^3/h$
Therefore power wasted in Rupees	= 0 157 x L x operating hours per year x cost per kWh

APPENDIX - 8/4

DETAILS OF LEAKAGE POINTS IN AIR DISTRIBUTION SYSTEM

Sl No	Location	Stem	Description	Qty.	Size
1	Concentrator plant	H_2 shut off valves	Entry hose fitting (rigid)	2	1 mm
2	- do -	Control valve to heat exchanger (Caustic)	- do -	1	1 mm
3	- do -	Inlet to vacuum release valve	-	1	2 mm
4	Cell house -2	Anolyte tank control valve	Hose fitting	1	1 mm
5	- do -	Control station DM water	Bells Fy- 604 cover	1	-
6	- do -	- do -	Hose fitting	1	-
7	- do -	Caustic dosing control valve 0701A	Bells cover leak	1	2 mm
8	- do -	HV 0701 & 0702 diaphragm valve	Hose fitting	1	2 mm
9	- do -	Diaphragm valve	Regulator inlet near hand rail 1005 hose fitting	1	-
10	- do -	Diaphragm valve X0609A	Regulator	1	-
11	- do -	Diaphragm valve S -last valve	Hose fitting	1	-
12	Cell house 2	Diaphragm valve 0615	Hose fitting	1	-
13	- do -	Diaphragm valve 0604B	Top hole	1	-
14	- do -	Diaphragm valve 0602	Gasket leak	1	-
15	- do -	H_2 Valve PDV 1001 D	Regulator leak	1	-
16	Cell House 1	Diaphragm valve 218	Gasket Leak	1	-
17	- do -	Control room panel board	All joints	5	-
18	Chlorine compressor	Safety valve	Suction hose fitting	1	-

APPENDIX - 8/5

APPLICATION OF FLAT BELTS IN LIEU OF V-BELTS IN AIR COMPRESSORS, AIR BLOWER, HYDROGEN BLOWER AND HYDROGEN COMPRESSERS

Item	Actual kW	Operating hrs/year	Annual energy consumption kWh/year
Air compressor - A	13 14	8000	105120
Air compressor - B	14 28	8000	114240
Air compressor - C	14 19	8000	113520
Air blower - B	1 33	8000	10640
H_2 blower - A	4 14	8000	33120
H_2 compressor - B	30 9	8000	247200
H_2 compressor - C	52 05	8000	416400

Based on proven applications and achievements at several plants a 3% energy saving is assumed

Annual energy savings which could be achieved are tabulated as below

Item	Annual Savings	
	kWh/year	Rs /yr
Air compressor - A	3154	5424
Air compressor - C	3427	5895
Air compressor - D	3406	5858
Air blower - B	319	549
H_2 blower - A	994	1710
H_2 compressor - B	7416	12756
H_2 compressor - C	12492	21486
TOTAL	**31208**	**53678**

Appendix - 8/5 contd.

The cost of implementation and payback period details are tabulated below

Sl No	Item	Annual savings (Rs /yr)	Cost of implementation (Rs)	Simple payback period (Years)
1	Air compressor - A	5424	20,000	3 7
2.	Air compressor - C	5895	20,000	3 4
3	Air compressor - D	5858	20,000	3.4
4	Air blower - B	549	10,000	18.2
5	H_2 blower - A	1710	10,000	5 8
6	H_2 compressor - B	12756	20,000	1 6
7	H_2 compressor - C	21486	20,000	0 94

APPENDIX - 9/1

DETAILS OF IAEC BOILER

1	Heating surface	- 49.29 m^2
2	Working pressure	- 10 5 kg/cm^2
3.	Capacity	- 2 T/HR
4	Burner Nozzle	- 160 kg/Hr
5	Blower size	- 50/28, 2900 rpm, 2175 m^3/hr 30 mm/Hg
6	Boiler size	- 1600 mm dia, 3900 mm long
7	Pressure drop	- 150 mm Hg max

APPENDIX - 9/2
Sht 1 of 2

FORMULAE EMPLOYED FOR CALCULATION OF VARIOUS HEAT LOSSES

Composition of Fuel (Furnace Oil)

Basis : 100 kg of fuel

C	: % carbon in FO	= 84
S	: % Sulphur in FO	= 4
H	: % Hydrogen in FO	= 12
T_F	: Flue gas exit temp (^oC)	= 198
T_A	: Ambient air temp (^oC)	= 35

Estimation of Combustion Air Requirement

1 Theoretical mass of air required in kg/100 kg of fuel (T_a)

$$T_a = 11.5C + 34.5\left(H - \frac{0}{8}\right) + 4.32\,S$$

2. % excess air in flue gas $= \left(\frac{Max.CO_2}{Act.CO_2} - 1\right) \times 100$

3 Total air supplied $=$ Theoretical air x $\left(1 + \frac{\text{Excess air}}{100}\right)$

4 Total flue gas $=$ Total air supplied + 1

5 Heat lost as sensible heat in flue gas (Hg)

$$= \frac{100}{12(\%\ CO_2)} \times \left\{\frac{C}{100} + \frac{S}{267}\right\} \times 30.6 \times (T_F - T_A)$$

6. Heat loss due to Hydrogen in FO

$$\text{kcal/kg} = \frac{9 \times (\%H)}{100} \times \{1\ 88\,(T_F - T_A) + 2442\}$$

7 Heat loss due to Moisture in air

$$\text{kg/kg} = \text{Actual air supplied} \times \text{Sp humidity of air} \times 1\ 88\,(T_F - T_A)$$

APPENDIX - 9/3

HEAT BALANCE AND THERMAL EFFICIENCY OF IAEC BOILER

a. Basic Data

I	Make of Boiler	= IAEC
ii	Steam generation capacity	= 2 T/Hr
iii	Fuel used	= FO
iv	No Of working hours	= 24 hrs/day
v	Gross calorific value	= 10,200 /kcal/kg
vi	Ambient air temperature	= 35°C

b. Estimation of Heat Losses Before Excess Air Control

I Theoretical air required

Ta = 11 5(84) + 34 5 (12) + 4 32 (4)
= 1397 28 kg/100 kg of FO
= 13 97 kg/kg of FO

ii Excess air = $\left(\frac{15\ 3}{8\ 5} - 1\right) \times 100$

= 80%

iii Total air supplied = 13 97 $\left\{1 + \frac{80}{100}\right\}$

= 25 15 Kg/kg of FO

Total flue gas = 25 15 + 1
= 26 15 Kg/kg of FO

Appendix - 9/3 contd

iv Heat loss due to sensible heat in flue gas

$$= \frac{100}{12 \times 8\,5} \times \left\{ \frac{84}{100} + \frac{4}{267} \right\} \times 306\,(198-35) \times \frac{1}{4\,18}$$

$$= 1002 \text{ kcal/kg}$$

$$\% \text{ Heat loss} = \frac{1002}{10200} \times 100 = 9.8\%$$

v Heat loss due to Hydrogen in fuel

$$= \frac{9 \times 12}{100} \times \{ 1\,88\,(198-35) + 2442 \} \times \frac{1}{4.18}$$

$$= 710 \text{ kcal/kg}$$

$$\% \text{ heat loss} = \frac{710}{10200} = 7\%$$

vi Heat loss due to moisture in air

$$= 28\,15 \times 0\,01 \times \{1\,88\,(198-35)\} \times \frac{1}{4.18}$$

$$= 18.44 \text{ kcal/kg}$$

$$\% \text{ heat loss} = \frac{18\,44}{10200} \times 100$$

$$= 0\,18\%$$

Appendix - 9/3 contd.

c. **Estimation of Heat Losses After Excess Air Control**

I Theoretical air required

= 13 97 kg/kg of FO

II Excess air $\left(\frac{15\ 3}{11\ 5} - 1 \right) \times 100$

= 33 04%

III Total air supplied $= 13\ 97 \left(1 + \frac{33\ 04}{100} \right)$

= 18 59 kg/kg of FO

IV Total flue gas = (18 59 + 1)

= 19 59 kg/kg of FO

V Heat loss due to sensible heat in flue gas

$$= \frac{100}{12 \times 11\ 5} \times \left\{ \frac{84}{100} + \frac{4}{267} \right\} \times 30\ 6\ (190-35) \times \frac{1}{4.18}$$

= 703 kcal/kg

% of loss = $\frac{703}{10200} \times 100 = 6\ 9\%$

Appendix - 9/3 contd

vi Heat loss due to hydrogen in fuel

$$= \frac{9 \times 12}{100} \text{ X } \{1\ 88\ (190\text{-}35) + 2442\} \text{ X } \frac{1}{4\ 18}$$

= 706 23 kcal/kg

$$\%\ \text{heat loss} = \frac{706\ 23}{10200} \text{ X } 100$$

= 6 92%

vii Heat loss due to moisture in ai.

$$= 18\ 59 \times 0\ 01 \times 1\ 88\ (\ 190\text{-}35) \times \frac{1}{4\ 18}$$

= 12.96 kcal/kg

$$\%\ \text{of heat loss} = \frac{12\ 96}{10200} \times 100$$

= 0 13%

HEAT BALANCE

Sl No	Particulars	Before excess air control %	After excess air control %
1	Heat input	100	100
2	Heat loss as sensible heat	9 8	6 9
3	Heat loss due to hydrogen in fuel	7	6 92
4	Heat loss due to moisture in air	0 18	0 13
5	Radiation and unaccounted losses	1.0	1 0
6	Thermal efficiency	82 02	85 05

APPENDIX - 9/4

FUEL CONSERVATION IN BOILER BY IMPROVING % CO_2 AND THERMAL EFFICIENCY

TRIALS CONDUCTED ON IAEC BOILER ON 11.6.97

TEST PROCEDURE

1 Boiler operation data collected on 11 6 97 from 9 30 am to 2 50 pm as per format in Appendix - 9/5

2 To vary excess air an attempt was made to operate the combustion system damper, but it failed to respond due to mechanical repair

3 The intake of combustion blower was then progressively masked to control inflow of air and thereby control excess air.

4 At 12 noon the % CO_2 increased from 8 5 to 11.5% after the fan intake was masked about 90%

5 The mask on the blower was fixed in this position to study fuel behaviour over the next few days

6 Fuel consumption data were analysed on dates prior and after the date of trial (i e 11 6 97) to assess consumption behaviour.

The results are as follows

	7 6 97	17 6 97
Full load	60 6 litrs/hr	-
Low load	-	37 1 l/hr
Derated full load	48 l/hr	-

The boiler has operated on 7 6 97 at full load and at low load on 17.6 97

During full load operation the boiler is always ON and does not shut OFF even for a few minutes since the steam demand is high.

Appendix - 9/4 contd

During low load operation for every 19 hours operation in ON condition, the Boiler is OFF (or no fire) for 5 hours. Accordingly, to compare the fuel consumption data of 7 6.97 and 17 6.97, the full load figures have been derated to match low load figures by the ratio of 5 19

The fuel scenario is now as below

	7 6.97	17 6 97
Fuel consumption	48 l/hr	37.1 l/hr
% CO_2	8 5	11 5

It is observed from the above that after the % CO_2 was increased by masking the blower intake the fuel consumption has reduced

However, in order to quantify the savings of fuel the following approach is adopted

$$\text{Efficiency} = \frac{\text{Steam flow rate x Enthalpy difference}}{\text{Fuel flow rate x Calorific value}}$$

The steam flow rate, enthalpy difference and calorific value remain a constant and can be designated as K_1

$$\text{Hence} = \frac{K_1}{F_1 \text{ (Fuel flow rate)}} = 82 \text{ in first condition}$$

$$= \frac{K_1}{F_2} = 85 \text{ in second condition}$$

$$\frac{F_2}{F_1} = \frac{82}{85}$$

$$F_2 = \frac{82}{85} \times F_1$$

Appendix --9/4 contd..

$$= \frac{82}{85} \times 48$$

	=	46 litres/h
Fuel savings	=	2 litres/h
	=	2 x 6476
	=	12952 litres/year
Hence energy savings	=	12952 litres/y
Value of savings	=	12952 x 5.6
	=	Rs 72531/year
Cost of implementation	=	Rs 50,000/-
Simple payback period	=	0 7 year

APPENDIX - 9/5

OPERATION STUDY OF BOILER ON 11.6.97

OBSERVATION DATA

Time	Furnace Oil			Furnace oil tank level reading	Feed water temp °C	Steam		Flue gas	
	Inlet pr kg/cm^2	Return pr. kg/cm^2	Temp °C			Pr kg/cm^2	Temp °C	Temp - °C	% CO_2
9 30 AM	20	3 8	90	74	43	6 5	195	198	9
10 30 AM	18	2 5	90	68	44	5.8	190	183	8 5
11 AM	14	3 9	94	62	45	5 2	190	183	8 5
12 Noon	15	3 8	91	57	45	6 1	190	189	11 5
12 20	-	-	-	53	-	-	-	-	11 5
1 40 PM	15	4	91	44	45	6 5	190	190	11 5
2 50 PM	15	4	90	34	45	6 8	190	190	11 5

APPENDIX - 9/6

SAVINGS BY UTILISING HOT CONDENSATE AS BOILER FEED WATER

Quantity of hot condensate being let out in the drain (considering 60% can be recycled)	= 1 02 x 0 6 m^3/h
	= 0 61 m^3/h
Net flow rate of condensate considering annual working hours as 6476	= 1 02 x 6476 x 0.6
	= 3950 m^3/year
Approx. Cost of DM water	= Rs.50/m^3
Hence annual cost of DM water now being replaced by condensate	= Rs 50 x 3950
	= Rs 1,97,518/year

Cost of implementation consists of insulated tank , insulated piping and pump

Approx Cost	= Rs 1,50,000
Simple payback period	= 0 8 year

APPENDIX - 9//7

STEAM LEAKAGES

Sl No	Location	Description	Size	Qty	Steam loss kg/h
1	Boiler room	Main outlet valve gland	2"	1	5
2	Boiler room	Water level indicator valve	2 mm	1	5
3	1st platform steam distribution centre	Valve	3"	1	7
4	Boiler room	Boiler bottom oil pre heater outlet pipe	3/4" dia	1	10
TOTAL STEAM LOSS					27 kg/h

Total steam loss	=	27 Kg/hr
	=	27x 6476
	=	1,74,852 kg/year
	=	174 8 T/year
Value of steam loss	=	Rs 250 x 174 8
	=	Rs 43,700/year
Value of savings	=	Rs.43,700/ year
Cost of implementation	=	Rs 25,000/-
Simple payback period	=	0 57 year

APPENDIX - 9/8

SURFACE HEAT LOSSES FROM UN INSULATED VALVES, FLANGES AND PIPELINES

Sl No	Location	Item	Nos	Size	Temp °C	Effective area m^2	Heat loss kcal/h
1	Boiler room main outlet	Valves Flanges Pipe	3 14 1 mtr	2" 2" 2"	160 160 160	0 27 1 4 0 2	579 3003 429
2	Opp DG set room	Valves Flanges	1 2 4	2" 3/4" 3/4"	160 160 160	0 18 0 1 0.2	386 214 429
3	Opp Hypo Section	Valves Flanges Pipe	2 8 1 mtr	3/4"	160 160	0.18 0 2 0 1	386 429 214
4	Lawn	Valves Flanges	5 10	1" 3/4"	160 160	0 45 0 25	965 536
5	Cell house 1 - Heat exchanger	Valve Pipe Valve	2 1/2 mtr 1	1/2 " 2" 3"	160 160 160	0 1 0 1 0 15	214 214 322
6	Chlorine Bottling Area	Flanges Pipe	2 2 Mtr	2" 2"	160 160	0 2 0 4	429 858
7	Cell House-2, Caustic cooler, Heat exchanger (hot water)	Pipe Pipe	2 Mtr 3 Mtr	1" 3/4"	99 99	0 16 0 17	149 158
8	Steam distribution station	Valves Flanges Pipe	3 4 11/2 mtrs	4" 4" 4"	160 160 160	0 9 0 5 0 47	1930 1073 1008
9	Brine solution heat exchangers	Valves Flanges Pipe	8 6 3 mtrs	4" 4" 3"		2 0 0.8 1 47	4290 1716 3026
	TOTAL						22956

Total surface heat losses = 22956 kcal/h

A conservative estimate assumes that about 65% of the heat losses could be successfully saved by insulating the exposed surfaces

Appendix - 9/8 contd.

Hence, heat savings	=	22956 x 0 65
	=	14921 kcal/hr
Equivalent steam savings	=	21 kg/hr
Steam savings/year	=	21 x 6476
	=	135996 kg/y
	=	136 t/y
Value of savings	=	Rs 250 x 136
	=	Rs 34,000/ year
Total area to be insulated	=	10 8 m^2
Cost of insulation	=	Rs 800/m^2
Cost of implementation	=	800 x 10 8
	=	Rs.8640
Simple payback period	=	0 25 year

APPENDIX - 9/9

SURVEY OF STEAM TRAPS

Sl No	Location	Qty	Condition	Remarks
1	Boiler Room Outside Bottom 3/4" pipe line	1	Not working removed	Continuously discharging
2	Outside DG set room	1	Leaking	To be replaced
3	Outside Hypo Area	1	Leaking	To be replaced
4	Lawn Area	2	One leaking	To be replaced
5	Cell house 1 process area	1	OK	

APPENDIX - 10/1

LOADING PATTERN OF PUMPS & BLOWERS

Application area	Design		Desired kW	Rated kW	Actual kW	% Loading	Specific gravity	Remarks
	Flow m^3/hr	Head m						
CELL HOUSE -1								
Brine Pump A	30	28	2 2	5 5	3 36	61	1 176	
RCC Pump	25	30	4 7	5 5	5 55	100	1 3175	
Depleted brine	18	18	2 0	7 5	4 92	66	1 173	η = 0 15
Dechlorinated pump	25	25	3 9	7 5	5 253	70	1 12	η =0 4
Hydrogen Blower	290	1100 MMWC	-	9 3	4 14	45	-	-
Air Blower	196	2 M	2 5	5 5 (3 7)	1 326	24		η = 0 5
Chlorine blower	800	1500 MMWC	-	15	9 66	64	-	-
Chlorine wash tower	15	20	1 6	3 7	1 1	30	-	-
Hydrogen wash tower	10	15	0 83	1 5	-	-	-	-
Pit water pump	15	12	0 72	2 2	-	-	-	Run rarely
Waste caustic pump	-	-	1 0	2 2	-	-	-	-
								-
CELL HOUSE 2								
Lean brine pump	25	25	3 7	5 5	3 18	58	1 12	η = 0 4
Catholyte pump	40	39	8 0	11 0	11 73	107	1 295	η = 0 4
Product caustic pump	7	42	3 2	7 5	4 08	54 4	1 315	-
Vacuum pump	10	-	-	5 5	4 65	85	-	-
HCL Pump A	3 5	18	0 5	3 75	-	1 155	-	Not running continuously
Alkali effluent pump	7 5	12	0 43	1 5	-	-	-	-
Acidic effluent pump	7 5	12	0 43	1 5	-	-	-	-
Hydrogen condensate pump	2 55	23	0 24	1 5	-	-	-	-
Brine Plant								
Saturator brine	25	50	7 5	11	5 5	50	1 12	-
Clarified brine								η=0 70
A	60	50	15	15	14 49	97	1 14	η=0 70
B	60	60	18	15	-	-	1 14	
Polished brine pump	60	52	15 5	18 5	12 87	70	1 15	η= 0 70
Pure brine	35	28	7 7	7 5	4 44	59	1 175	-

Appendix - 10/1 contd .

Application area	Design		Desired kW	Rated kW	Actual kW	% Loading	Specific gravity	Remarks
	Flow m^3/hr	Head m						
Raw water								
B	40	25	5 0	3 7	3 14	85	1 00	η= 0 6
C	40	25	5 3	7 5	6 3	84	1 00	η = 0 6
Recover brine tank (RBT)	18	35	3 3	2 2	1 22	55	-	-
Brine bore well	40	30	6 5	9 2	5 25	57	-	-
Sludge B	10	20	-	2 2	0 447	20	-	-
Sludge C	10	20	-	2 2	1 914	87	-	-
RECTIFIER 1&2								
DM Water 2 A,B	-	-	-	2 2	1.95	89	-	-
Transformer oil pump A,B	28 5	12	1 8	3 5	3 2	91	0 8	-
Cooling water return	-	-	-	11 2	10 74	96	-	-
Raw water return "P"$_2$AB	-	-	-	-	-	-	-	Not run
DM water 1A,B	-	-	-	2 2	2 1	99	-	-
Transformer oil pump A,B	66	11	3 1	3 2	2 67	83	0 8	-
LIQCHLOR PLANT								
C hilled water pump A,B	70	50	18 5	18 5	14	76	1 0	-
Cooling water Pump A,B	200	20	16 0	18 5	16 83	91	1 0	-
Acid circulation P_1 A,B	15	18	2 2	2 2	2 3	1 00	1 7	-
Acid circulation "P2" A,B	22	-	5 5	5 5	3 57	65	1 7	-
SODIUM HYPO PLANT								
Hypo blower	1000	-	-	15 0	3 57	23 8	-	-
Hypo dilution pump	-	-	-	2 2	0 81	37	-	-
Circulation pump A	12	15	1 1	2 2	1 95	88 6	1 188	η= 0 15
Circulation pump C	12	15	1 1	2 2	1 26	57 0	1 08	η= 0 2
Guard tower pump	12	12	1 0	2 2	0 61	28	1 30	-
BOILERS AND UTILITIES								
Cooling water pump	600	40	77	79 6	66 6	84	1 0	-
Boiler feed pump	-	-	-	3 7	3 2	86	1 0	OK
RC feed pump	7 5	16	0 7	2 2	1 09	50	1 0	η=0 4
DM water pump B	12	45	2 9	3 7	2 6	70	1 0	-
DM Water pump C	25	65	8 7	5 5	4 0	73	1 0	-
RO high pr pump	8	225	9 6	15	13 62	90 8	1 0	η=40
Filtered water pump	14 4	39	3 0	5 5	4 0	73	1 0	-

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Appendix - 10/1 contd .

Application area	Design		Desired kW	Rated kW	Actual kW	% Loading	Specific growth	Remarks
	Flow m^3/hr	Head m						
STORAGE								
Caustic storage pump E	20	15	2 1	3 7	4 02	108	1 317	η=30
Caustic storage pump "A"	25	25	4 5	7 5	5 01	67	1 317	-
48% NaoH circulation pump	20	15	2 1	2 2	2 1	95	1 317	-
CONCENTRATION PLANT								
Thermic fluid pump	100	80	37	37	24 78	67	0 86	η=32%
Caustic evaporation pump	25	25	3 7	3 7	3 6	97	1 317	η=70
Vacuum pump	330	710 mm of Hg	-	11	7 77	71	-	-
SAAKE Blower	-	-	-	5 5	5 01	91	-	
BARIUM SULPHATE PLANT								
Clear brine pump	12	18	1 4	5 5	3 66	66 5	1 175	η=25
Product slurry pump	5	30	1 1	3 7	3 20	86 0	1 6	η=25
Crude slurry pump	5	12	0 5	3 7	2 56	69 0	1 6	η=20

APPENDIX - 10/2

OBSERVATIONS ON DISCHARGE PRESSURE

A. CELL HOUSE - I

Application Area	Rated kW	Actual kW	Pressure (kg/cm^2g)		% Load	Remarks
			Design	Actual		
Depleted brine pump `B'	7 5	4 92	1 8	1 4	65 6	-
Caustic circulation pump	5 5	5 5	-	2 9	100 0	-
Chlorine wash pump	2 7	1 1	2 0	1 8	30 0	-
Air blower	5 5	1 3	0 2	0 15	24 0	-
Hydrogen blower	9 3	4 14	0 11	0.1	44 5	Part goes to Hcl and TFH, part goes to hydrogen holder
Hydrogen wash tower pump	1 5	-	1 5	1 55	-	-
Dechlorinated brine pump	7 5	5 25	2 5	3 7	70	Part goes to $BaSO_4$ plant , part goes to saturator
Secondary pure brine pump	5 5	3 36	2 0	1 3	61	Pumps to overhead tank

B. CELL HOUSE - II

Application Area	Rated kW	Actual kW	Pressure (kg/cm^2g)		% Load	Remarks
			Design	Actual		
Depleted brine pump `A'	7 5	4 44	2 8	N W	59 2	-
Catholyte pump `A'	11	11 73	3.9	5 2	106 0	-
Polished brine pump `B'	18 5	12 87	5 2	3 9	70 0	-
Lean brine pump `A'	5 5	3 18	2 5	2.5	58 0	-
Product NaoH transfer pump `A'	7 5	4 08	4 3	2.8	54.0	
Vacuum pump `A'	5.5	4 65	-	-	85	-
Rectifier oil pump `A'	3.2	2 67	-	-	83	
Rectifier - II D M water pump	2 2	1 95	-	-	89.0	-

APPENDIX - 10/3

ESTIMATION OF EFFICIENCY OF THERMIC FLUID HEATING PUMP

A. Basic data

(I) Actual power input to pump = 24 78 kW

(ii) Specific heat at 100°C = $\frac{0\ 466 \quad \text{Btu}}{\text{Lb}^\circ \text{F}}$

300°C = 0.578

Average specific heat @ 215°C = $\left(\frac{0\ 578 - 0\ 466)}{200}\right. \times (215\text{-}100) + 0\ 466$

= $\frac{0\ 5304 \quad \text{Btu}}{\text{Lb}\ ^\circ\text{F}}$

= $0.5304 \times 4\ 186 \quad \frac{\text{KJ}}{\text{kg}^\circ\text{K}}$

= $\frac{2\ 22 \quad \text{KJ}}{\text{kg}^\circ\text{K}}$

(iii) Discharge head = 58 m

Appendix - 10/3 contd..

B. Derived Data

Actual power input to the pump is calculated using this formula

$$\text{Actual power} = \frac{\text{Theoretical power}}{\text{Eff Of pump x Eff. of motor}}$$

$$\text{Theoretical power} = \frac{\text{Flow (m}^3\text{/hr) X Head (m) X 9 81 X Sp gravity}}{3600}$$

$$\text{Hence, Theoretical power} = \frac{\text{Flow x 58 x 9 81 x 0 86}}{3600}$$

(Pump is run in low load condition, Hence a flow of around 49 m^3/hr is arrived at by trial and error as to match the useful heat worked out earlier For this flow, corresponding, efficiency of pump is worked out to be 32%)

C. Matching useful heat in thermic fluid

(I)	Inlet thermic fluid temperature	=	175 °C
(II)	Outlet thermic fluid temperature	=	215 °C
(III)	Derived flow	=	49 m^3/sr

$$\text{Useful heat} = \frac{49 \times 0.86 \times 2\ 23 \times (215\text{-}175) \times 1000}{3600}$$

= 1039 kW

= 893540 kcal/h

APPENDIX - 10/4

ENERGY SAVINGS BY REPLACING EXISTING THERMIC FLUID HEATING PUMP BY NEW PUMP

Basis

(I)	Estimated flow	=	50 m^3/hr
(ii)	Estimated operating head	=	58 m
(iii)	Estimated efficiency of new pump operating at this flow It is assumed to have max efficiency to be 60%	=	45%
(iv)	Estimated efficiency of motor	=	80%
(v)	Theoretical power	=	$\frac{50 \times 58 \times 9\ 81 \times 0\ 86}{3600}$
		=	7 6 kW
(vi)	Actual power	=	$\frac{7\ 6}{0\ 45 \times 0\ 80}$
		=	21 kW

Appendix - 10/4 contd..

(vii)	Actual power drawn presently	=	24.78 kW
(viii)	Energy savings	=	24 78 - 21
		=	3 78 kW
(ix)	Annual energy savings	=	3 78 x 8000 x 1.72
		=	Rs 52,000
(x)	Estimated investment	=	Rs 1,00,000
(xi)	Simple payback	=	$\frac{100000}{52000}$ = 2 Years

APPENDIX -10/5

ENERGY SAVINGS BY REPLACING EXISTING INEFFICIENT PUMPS BY NEW EFFICIENT PUMPS.

Pump Reference	Actual Values		Estimated Efficiency	Improved Efficiency	Present Power in-put kW	Improved Power in-put kW	Annual Energy Savings kWh	Annual savings Rs	Estimated Invest-ment Rs	Simple payback year
	Flow (m3/hr)	Head (m)								
CELL HOUSE 1										
Depleted brine	14	14	15	50	4 92	1 5	27360	47000	50000	1
Dechlorinated pump	16	37	40	55	5 253	3 9	10800	18600	70000	3 8
CELL HOUSE 2										
Lean brine pump	14	25	40	55	3 18	2 3	,7040	12100	70000	5 6
SODIUM HYPO PLANT										
Circulation pump C	10 4	7	20	50	1 26	0 5	6080	10500	40000	3 8
Circulation pump A	9 6	8	15	50	1 95	0 6	10800	18500	40000	2 2
BOILERS & UTILITIES										
RO feed pump	7 5	18	40	50	1 09	0 9	1520	2600	10000	3 8
RO high pr pump	8	225	40	55	13 62	10 5	24960	42900	128000	3
STORAGE										
Caustic storage pump	20	15	30	50	4 02	2 5	12160	20900	40000	1 9
BARIUM SULPHATE PLANT										
Clear brine pump	12	18	25	50	3 66	1 4	18080	31000	60000	1 9 -
Product slurry pump	5	30	25	50	3 2	1 5	13600	23400	60000	2 6
Crude slurry pump	5	12	20	40	2 56	0 8	14080	24200	50000	2
Total							146460	251700	618000	2.5

For titanium pumps only impeller costs have been considered
Savings have been projected based on 8000 hrs operation
Improved efficiencies are based on practicable values As for as possible lower achievable values have been considered

APPENDIX - 11/1

COOLING TOWER SPECIFICATIONS

A. COOLING TOWER

			Main Cooling Tower	Lich Chlor Cooling Tower
(i)	Type	=	Induced draft	Induced draft
(ii)	Water flow rate	=	525 m^3/h	250m^3/h
(iii)	Inlet temperature	=	41^{o}C	41 ^{o}C
(iv)	Outlet temperature	=	31 ^{o}C	31 ^{o}C

B. COOLING TOWER PUMP

(i)	Capacity	=	600 m^3/h	200 m^3/h
(ii)	Head	=	40 metres	25 metres

C, COOLING TOWER FAN

(I)	Fan speed	=	444 rpm	-
(ii)	No of blades	=	4	6
(iii)	Fan blades	=	Aluminium	Aluminium
(iv)	Dia of fan	=	96"	144"
(v)	Capacity	=	175 M^3/h/ fan	-
(vi)	Nos.	=	3	1

D. MOTOR

(I)	TEFC Weather proof 1P55		
(ii)	Rating/rpm - 18 5 kW/1450 RPM	3x18,5/1450	15kW/1400
(iii)	Volts - 415 ± 10% V		
(iv)	50 Hz 3 phase		

APPENDIX - 11/2

OBSERVATIONS OF MAIN COOLING TOWER PARAMETERS

A. Observed Parameters

Date : 13.06.97

Time (hrs)	Cooling Water Temp (^{0}C)				Cooling Water Temp (^{0}C)		Ambient air	
	inlet (^{0}C)		Outlet (^{0}C)		D B	W B	Inlet	Outlet
Cell No	1	2	1	2			3	3
9.00	32 5	33 5	28 6	29 0	28	26 0	32 5	27 5
1000	34 0	34 0	29.5	29 0	27 5	25 5	33 0	27 5
1145	33 5	34 0	29 5	29 0	30 5	27.0	33 5	28 0
1330	34	34 0	29 5	29 5	32 5	27.5	33 5	28 5
1545	34	34 5	30	29 5	32 0	28 0	34 5	29 5

B. Range and Approach Values

Range (^{0}C)			
Time	Cell 1	Cell 2	Cell 3
9.00	3.9	4 5	5
10.00	4 5	4.5	5 5
11 45	4	5.0	5 5
13.30	4.5	5 0	5
15 45	4	5.5	5
Avg	4 18	4.9	5 2

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Appendix - 11/2 contd.

Approach (^0C)			
Time	Cell 1	Cell 2	Cell 3
	(^0C)	(^0C)	(^0C)
9 00	2.6	3.0	1.5
10.00	4.0	4.0	2.0
11 45	2 5	2.5	1 0
13.30	2 0	1.5	1.0
15 45	2 0	1.5	1.5
Avg.	2.62	2 5	1.4

C Make up water calculation

(i) Cell 1 & 2 - (Conc. Plant + Cell house 1 + Cell house 2)

Evaporation loss = 0.00085x378x{4.54} x 1.8 m^3/h

= 2.62 m^3/h

Drift loss = 2.62x0 002

= 0.00525 m^3/h

Blow down = $\frac{\text{Evaporation loss}}{\text{(Conc Cycle - 1)}}$

= $\frac{2.62}{(4 - 1)}$

= 0.87 m^3/h

Make up water = 2.62 + 0.00525 + 0.87

= 3.495 m^3/h

Appendix - 11/2 contd.

(ii) HCL Cell

Evaporation loss = 0 00085x130x5.2x1 8
= 1.034 m^3/h

Drift loss = 1 03x0.002
= 0.00206 m^3/h

Blow down = Evaporation loss / (Conc Cycle - 1)

= 1 034 / 3

= 0 345 m^3/h

Make up water = 1 381 m^3/h

(iii) Total make up water = 4.876 m^3/h
= 117 m^3/day

D. Measured Air Flow Rate at Discharge of Fans

	Cell 1	Cell 2	Cell 3
Fan dia	96"	96"	96"
Measured frequency	45 Hz	45 Hz	45 Hz
Measured average Velocity (m/s)	14	12	13 3
c/s area (m^2)	4 7	4.7	4 7
Average flow (m^3/h)	66	56	63

(d) Measured dry bulb and wet bulb temperatures at exit of fans

Time	Cell 1		Cell 2		Cell 3	
	DB ^0C	WB ^0C	DB ^0C	WB ^0C	DB ^0C	WB ^0C
12.00	30 5	29 5	30 5	29.5	30.5	28.5
13 45	32 5	30	32 5	30	32 5	29 5

APPENDIX - 11/3

ASSESSMENT OF HEAT LOADS OF MAIN COOLING TOWER

A Distribution of Cooling water heat loads

Cooling water user Area	Measured Flow m^3/h	Avg. Temp. rise °C	Heat Load kcal/h	% heat load
Concentrator plant of cell house-I + cell house-II	378	4.54	17,16,120	73
Hydrochloric acid plant	130	5	6,50,000	27
		Total	23,66,120	100

B Distribution of cooling water heat loads excepting Hydrochloric acid plant

user Area	Measured Flow m^3/h	Avg. Temp. rise °C	Heat Load kcal/h	% heat load
Concentrator plant Surface condenser caustic PHE- I Caustic PHE-II	 131 13 7	 8 9 13	 10,48,000 1,17,000 91,000 12,56,000	53
Cell House II Hydrogen Cooler Chorine cooler	 51.52 48 65	 2 5 2.5	1,28,800 1,21,625 2,50,425	11
Cell House -I	127	1.7	2,09,695	9

C i Design heat load = 525 X 1000 X 10

= 52,50,000 kcal/h

ii Actual heat load = 23,66,120 kcal/h

iii. Percentage of design load = $\frac{23,66,120}{52,50,000}$

= 45%

APPENDIX - 11/4

MEASURED COOLING WATER FLOWS IN VARIOUS USER AREAS

A Main Cooling Tower

Application Area	Pipe Nominal dia	Pipe outer dia (mm)	Wall thickness (mm)	Measured Velocity (m/s)	Measured flow m^3/h	Remarks
Suction Line						
Suction inlet from HCL cooling water supply pump pump suction	14 10	359 270	5 3 5 18	0 32 1 25 to 1 38	116 472 to 508	- -
Discharge line						
Cooling water supply to cell house-I area	8	218	4 37	1 8	249	Sampling point not fully O K due to location
Cooling water supply to concentration unit	6	170	4 58	1 85	144	Surface condenser and one heat exchanger
Supply to surface condenser	6	170	4 7	1.69	131	-
Supply to Hydro chloro acid plant	6	170	4 2	1 64	130	-
Supply to chlorine cooler (cell house-II)	3	89	4 39	2 62	48	-
Supply to hydrogen cooler (cell house-II)	3	89	4 57	2 82	51	-

B. Liquid Chlorine Cooling Tower

Application Area	Pipe Nominal dia	Pipe outer dia (mm)	Wall thickness (mm)	Measured Velocity (m/s)	Measured flow m^3/h	Remarks
Main discharge line	8	220	3 9	1 86	246	-
Freon comp 'B' condenser water	4	113	4 34	1 01	32	Cond flow exists in machine 'A'
Chilled water m/c-1 condenser water	6	170	5 2	1 24	95	No cond flow in machine-2
Freon com 'A' condenser water	4	113	5 49	1 02	31	-
Supply line to air compressor	3"	85	3 91	0 46	7 8	-
Return line to air compressor	3"	85	3 91	0 45	7 5	-
Cooling tower return line	8	220	4 3	1 46	184	-

APPENDIX - 11/5

OBSERVATIONS MADE ON LIQCHLOR COOLING TOWER

Date: 12.6.97

Delivery pressure of pump = 2 kg /cm^2

Make up water temp. = 27^{0}C

Time	Water Inlét temp ^{0}C	Water Outlet temp ^{0}C	Dry bulb temp ^{0}C	Wet bulb temp ^{0}C
9 am	33	30	28	26
10 am	33	30	-	-
11 am	33	30	-	-
12 Noon	33	30	-	-
1 pm	33	30	-	-
2 pm	33	31	32	28
3 pm	33	31	32	30
4 pm	33	31	-	-
5 pm	33	31	30	28
6 pm	32	30	-	-

APPENDIX - 11/6

MAKE UP WATER REQUIREMENTS

A. Make up water requirement is evaluated using the following relation

M = E + C + B

Where E = Evaporation loss

C = Drift loss

B = Blowdown volume

Evaporation loss = 0.00085 x 184 x 2 4 x 1 8

= 0 68 m^3/h

Drift loss = 0.68 x 0 002

= 0 0014 m^3/h

Blowdown = $\dfrac{\text{Evaporation loss}}{(\text{Conc Cycle} - 1)}$

= $\dfrac{0\ 68}{4 - 1}$ = 0.23 m^3/h

Makeup water = 0 68 + 0 0014 + 0 23

= 0 91 m^3/h

B. **Heat Load**

Heat load = Q x average range

= 134 x 2 4 x 1000

= 4,41,600 kcal/h

APPENDIX - 12/1

Sht 1 of 3

LIGHTING LOAD MEASUREMENTS

Sl No	Lighting D.B Details	Phase	Measured				
			Volt	Amps	Cos ϕ	kVA	kW
1	Street light MCB	R	229	1 39	0 85	0.32	0 29
		Y	231	8 24	0 98	1 89	1 54
		B	228	6 87	0.98	1 57	1 40
2	110kV Switchyard MCB	R	237	2 76	0.91	0 64	0 49
		Y	232	2.31	1 00	0 54	0 49
		B	229	4 93	0.99	1.13	1.02
3	Executive office MCB	R	231	1.27	0.30	0.29	0 11
		Y	-	-	-	-	-
		B	-	-	-	-	-
4	H T Room MCB	R	230	6 80	0 92	1 54	1 34
		Y	-	-	-	-	-
		B	-	-	-	-	-
5	MCC - 1 & QC Lab MCB	R	231	10 27	0.95	2 38	2.35
		Y	232	5.58	0 87	1.30	1 22
		B	228	5 20	0 91	1 18	1 10
6	Rectifier Room - 2 MCB	R	230	4.67	0 96	1 07	0 99
		Y	231	4.93	0 99	1 14	0 99
		B	226	2 35	0 63	0 52	0.35
7	Cell House # 2 MCB	R	230	2 81	0 85	0 64	0 52
		Y	-	-	-	-	-
		B	231	6 27	0 81	1 42	1 13
8	Rectifier Room - 1 MCB	R	230	12.82	0 86	2.95	2 33
		Y	231	7 44	0 95	1.72	1.53
		B	226	4 09	0 84	0 92	0 69
9	MCC - 5 & Liqchlor MCB	R	231	9.44	0.99	2.17	2.04
		Y	233	10.69	0 98	2.48	2 22
		B	227	12.40	0 86	2.83	2 22
10	Boiler House MCB	R	230	5.87	0 95	1.62	1.34
		Y	232	10.95	0 90	2.54	2.43
		B	227	2.21	0 99	0.50	0.42
	TOTAL					35.32	30.52

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Appendix - 12/1 contd..
Sht 2 of 3

LIGHTING FIXTURE DETAILS

Sl No	Area	Fan		GLS		TL X 40		TL2 x 40		ML 160		HPMV 125		HPMV 250		50 W 70		50 W 150		50 W 250		50 W 400		FLO 18 W	
		A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U
1	Brine Lab	1	1				6	4																	
2	Central lab	2	1	2	-	7	5																		
3	Brine area			1	1	5	5	4	4									1	1			2	2		
4	Conc plant					2	2									7	7								
5	Boiler house							10	9																
6	DM $H_2$0 Plant					5	5	5	3																
7	DG Room							8	3																
8	Hypo Plant					1	1	3	3	1	1														
9	R & D Lab																								
10	Storage									4	4														
11	P I CH													10	8					10	8				
12	P- I Process area QF					1	1	2	2									1	1						
13	P-II Process area GI							1	1	1	1					6	6								
14	P-II Cell House			2	2	3	2	4	2					3	3									12	12
15	Liqclor Comp			3	3	12	12											1	1						
16	Liqchlor D Tower					2	2			7	5							1	1						
17	Liqchlor Storage			4	4																				
18	Liqchlor Filling			1	1							8	8												
19	Liqchlor Testing					4	4																		
20	Control room- I					12	4																		
21	Control room - II			9	-	7	1																		
22	Rect-I Room	1	1			13	4																		

Appendix - 12/1 contd..
Sht 3 of 3

Sl No	Area	Fan		GLS		TL1 x 40		TL2 x 40		ML 125		ML 160		ML 250		50 W 70		50W 150		50W 250		50W 400	
		A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U	A	U
23	Rectifier - II							6	5					4	2					1	1		
24	HT Room					2	1	18	5											1	1		
25	Workshop	4	2					14	11														
26	MCC Room							6	-														
27	Project Office	8	2					8	2														
28	110 kV Yard																			8	8		
29	Street light					2	2											32	22				
30	Sec Office																						
31	Marketing																						
32	Personnel																						
33	Telex																						
34	Stores																						
35	Plant Office					2	1	6	2														
36	Exec Office	6	-			1	-	8	-														
37	$BasO_4$							4	2									1	1				
38	H_2 Bottling											29	17										
39	MCC - 12					2	1																
40	HCL Tower					1	1					9	8										
41	Hypo Toilet																						
42	Liqchlor Toiler																						
43	7 5 T Air room			1	1							2	-										
44	P-II P A Ist Floor					1	1					2	1										
45	P-II PA II Floor											2	-				2	2					
46	P-II PA Top											2	-					1	1				

Note . A = Available fixtures, U = Fixtures in use

APPENDIX - 12/2
Sht 1 of 5

LUX LEVEL MEASUREMENTS

Sl. No.	Location Details	Measured Lux Level	Remarks
1	**HT ROOM**		
a	PCC panel area front	140	-
b	110 kV metering & OLTC panel	80/60 (Front) 60/80 (Rear)	-
c	22 kV panel (Front)	80/180/80	-
d	22 kV panel (Rear)	40/200/60	-
e	Aux Transformer area (Outdoor)	0/40/40	-
f	Harmonic filter year (G O S)	40	-
g	Work table	160	-
2	**WORKSHOP**		
a	Entrance	20	-
b.	Grinding bench	80	-
c.	Lathe machine	40	-
d.	Drilling machine	40	-
e.	Work table	400	Lux level high, reflector to be removed
3.	**MCC - 5 & 6 AREA**		
a.	MCC - 5 panel (Front)	140	-
b.	MCC - 6 panel (Rear)	260	-
c	Project office work table	80/80	-
d.	Chilled water pump area (liqchlor)	20	-
4	**LIQCHLOR COMPRESSOR ROOM**		
a	Compressor main starter panel	120	-
b	Shift work table	60/40	-
c	Chlorine compressor - A/Roof	100/60	-
d	Chlorine compressor - B/Roof	120/80	-
e	Chlorine compressor - C/Roof	200/0	-
f	Chlorine compressor - D/Roof	20/60	-
g	Receiver area	100	-
h	H_2SO_4 storage tank area	40	-
i	Liquid chlorine storage tank roof	60/120/40/80	-
j	Heat exchanger chilled water drying tower (Ist floor)	100	-
k	Heat exchanger chilled water drying tower (2nd floor)	20/40	-
l	Heat exchanger chilled water drying tower (3rd floor)	120	-
m	Heat exchanger chilled water drying tower (4th floor)	20	Lamp position to be relocated for better staircase & equipment area lighting
n	Liquid chlorine cylinder yard	20	-
o	Liquid chlorine cylinder testing	40	-
p	Liquid chlorine cylinder loading	20	-

Appendix - 12/2 contd..
Sht 2 of 5

Sl No	Location Details	Measured Lux Level	Remarks
q	Liquid chlorine filling 1/2/3/4	20/40/120/100	
r	Liquid chlorine cylinder filling compressor area	40	-
5	**RECTIFIER TRANSFORMER 3 1 ROOM**		
a	Transformer DM water pump area	60	-
b	Rectifier bus area	60/80/80/60	-
c	MCC - 2 Panel	20	
6	**CELL HOUSE # 1**		
a	Cell house main cell area	220/180/100/80/60	-
b	Lab table	100	-
c	Cell 9 area	120	-
d	Cell 2 area	80	
e	Chlorine blower area	0	Area illumination is very less
	CELL HOUSE # 1 PROCESS AREA		
f	H_2 Blower	0	Area illumination is very less
g.	Caustic cooler	40	-
h	Acid dozzing	60	-
i.	Ist floor	20	-
j	2nd floor	60	-
k	Control room	160/240/80/60	-
l	Engineer's room	160/80	-
7	**CELL HOUSE # 2**		
a	Cell 1 area	20	-
b	Cell 1 & 2	140	-
c	Cell 2 & 3	180	Illumination is very poor
d	Control room	120/180/180/100	-
	CELL HOUSE # 2 PROCESS AREA		
e	Polished brine pump	40	-
f	Dry sulphate dozzing area	20	-
g	Vacuum tank	180	-
h	Anolyte tank control valve	20	-
i	Lean brine pump	20	-
j	Catholyte tank	20	-
k	Effluent pumps	20	-
l	NaoH intermediate pump	80	-
m	NaoH cooler	20	-
n	Caustic buffer pump	40	-
o	CW pump and tower area	0	Illumination is very poor
p.	Chlorine filter	40	-
q	Vacuum pump	60	-

Appendix - 12/2 contd .
Sht 3 of 5

Sl. No	Location Details	Measured Lux Level	Remarks
r	Brine heat exchanger	0	Illumination is very poor
s	H_2 filter	100	-
t	Hach analyser	60	-
u	Brine flow meter	0	Illumination is very poor
w	Control valve area	40,20	-
x	Brine OH tank, NaoH & H_2 cooler area	0	Illumination is very poor
y.	Acid, NaOH dozzing tank	0	- do -
8	**HCL TOWER**		
a	Tank ground floor	20	-
b.	Filters/floor	40	-
c.	HCL burner	80	-
d	Control panel	60	-
e	Chlorine shut off valve area	0	Illumination is very poor
f	Hcl stack	20	-
9	**RECTIFIER TRANSFORMER # 2**		
a.	DM water pump area	120	-
b	DC breaker area	120	-
c	MCC 9E (Front)	20	-
d	MCC 9E (Rear)	200	-
e.	MCC 9N (Front)	200	-
f	MCC 9N (Rear)	160	-
g.	AC/DC panel (Front)	20	-
h	Polarisation panel	20	-
10	**NAOH STORAGE AREA**		
a	Storage pumps	40/40/20	-
b.	Hcl storage pumps	20	-
11	**R&D LAB AREA**		
a.	R&D lab room	80/60	-
b.	Hypo blower area	20/100	-
c	1st floor circl tower	40	-
d	2nd floor circl tower	20	-
e	Hypo circulation pump	80	-
f	NaoH dilution tank	20	-
g	Gaurd tower	0	Illumination is very poor
12	**DG SET ROOM**		
a	MCC - 3 panel (Front)	40	-
b	MCC - 3 panel (Rear)	60	-
c	AMF panel (Front)	40	-
d	AMF panel (Rear)	80	-
e	DG Set	80/40	-
f	Main DM water storage area	20	-
g	DM water plant	20	-
h	R O Plant	80	-

Appendix - 12/2 contd..
Sht 4 of 5

Sl No	Location Details	Measured Lux Level	Remarks
13	**BOILER HOUSE**		
a	Compressor A,B, C	40	-
b	Shift table	60	-
c	MCC - 10 panel	60	-
d	MCC - 4 panel (Front)	60	-
e	MCC - 4 panel (Rear)	60/60	-
f	Boiler area	100/80/60	-
14	**CONCENTRATION PLANT**		
a	Boiler	40	-
b	Boiler panel	20	-
c	48% intermediate tank	60	-
d	NaOH transfer pump	40	-
e	Ist floor caustic flow meter/vacuum pump	60/60	-
f	2nd floor area	40	-
g	3rd floor area	100/0	-
h	Pot 1 top	20	-
i	Pot 2 top	0	Illumination is very poor
15	**SALT YARD**		
a	Salt yard illumination	20/0/20	-
b	Between saturator B &C	20/40	-
c	Sludge filter press	20	-
d	Clarifier	20	-
e	Brine filter	40	-
f	CBT pump	20	-
g	Chemical dozzing area	40	-
h	Alfa cellulose dozzing	40	-
i	Clarifier top	40/40/40	-
j	Reactor top	40	-
k	Pre coat filter top	20	-
16	**$BaSO_4$ PLANT**		
a	$BaSO_4$ plant area	40	-
b	$BaSO_4$ filter press	40/40	-
c	MCC - 12	40	-
d	Sludge pump A, B, C	20	-
e	Raw water pump	0	Illumination is very poor
17	**BRINE LAB AND QC LAB**		
a	Brine lab	80	-
b	MCC - 1 panel (Front)	80	-
c	MCC - 1 panel (Rear)	140	-
d	QC lab	140	-
e	Oven	160	-
f.	Work table	80	-
g	Cabin QC	40	-

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Appendix - 12/2 contd
Sht 5 of 5

Sl No	Location Details	Measured Lux Level	Remarks
18	**HYDROGEN COMPRESSOR AREA**		
a	H_2 compressor - A & B	40	-
b	H_2 compressor - B & C	40	-
c	H_2 compressor - C	60	
d.	H_2 truck filling	40/20/40/40	-
e	Cylinder filling	40	-
19	**110 kV SWITCH YARD**		
a.	110 kV Main transformer	40/60	-
b	Current transformer	40/40	-
c	Isolator	40/40	-
d	Breaker	40/40	-
20	**NaOH FILLING AREA**		
a	Pump - 1	20	-
b	Pump - 2	40	-
c.	Pump - 3	20	-
21	**PLANT MAIN STREET**		
a.	Near NaOH filling station	40	-
b.	Weigh bridge area	40/20	-
c	Near Hcl tower	40	-
d.	Near boiler house	40	-
e.	Security main gate	60	-
f	Security office	80/100/80	-
g	Ganapathy bridge	140	-
h	Colony entrance gate	20	-
I	Colony main road	40/40/20/40	-

APPENDIX - 12/3

USE OF VOLTAGE CONTROLLERS

The total connected load (as measured)	=	30 5 kW
Present voltage level observed	=	226 - 233 V

If voltage level is reduced by 8 - 10% (I 3 210 - 215 V) then, 10-15% energy savings can be achieved

	=	13359 kWh
∴ Energy savings per annum	=	3.05 x 12 x 365 days (taking 10% savings)
Cost of energy savings per annum	=	Rs 22,977 50/- @ Rs.1.72/kWh
Cost of implementation of 45 kVA 3 ϕ Beblec P 20 energy saving device	=	Rs 85,000/-
Simple payback period	=	3 7 years

APPENDIX - 12/4

CASE STUDY FOR INSTALLING ELECTRONIC CHOKES FOR 36 W FLUORESCENT TUBES

Energy consumed by a single tubelight with standard choke	= 55 W
Energy consumed by the light fitting after replacement with electronic choke	= 45 W
Total No of tubelights in plant	= 214
Annual energy savings	$= \dfrac{10 \times 214 \times 12 \times 365}{1000}$
	= 9373 kWh
Cost of savings per annum @ Rs 1 72 / kWh	= Rs 16121 /-
Cost of one electronic choke	= Rs 300/-
Cost of implementation	= Rs 64,200/-
Simple payback period	= 3 98 Years

APPENDIX - 13/1

LIST OF SUPPLIERS AND RETROFITS

Eqpt./Retrofit	Manufacturer
Lighting	Beblec (India) Ltd 126, Sipcot complex Hosur 635 126, Tamilnadu Electronics India 238/A, 10th Main Road Nagendra Block, BSK II Stage Bangalore 560 050
Capacitors	Asian Electronics Ltd D-11, Road No 28 Wagle Industrial Estate Thane - 400 604 Marketed by Mysore Sales Intl Ltd Industrial Products Dvn MSIL House, 36, Cunningham Road Bangalore 560 052 Meher Capacitors Pvt Ltd 16(K), Attibele Industrial Area Neralur 562 107 Bangalore District Marketed by : Larsen & Toubro Limited P O Box 119, Pune 411 001 Prabhodan Capacitors Mfg by Seva Engg.Works Saswadi, Pune Crompton Greaves Ltd Dr E Moses Road Worli, Bombay 400 018

Appendix - 13/1 contd

Eqpt./Retrofit	Manufacturer
Energy Efficient Motors	Siemens Limited Jyothi Mahal II Floor St Marks Road, Bangalore 560 001
	Crompton Greaves Limited Machine I Division Dr E Moses Road Worli, Bombay 400 018
Variable Speed Drives	Asea Brown Boveri Ltd Sona Towers, 71, Miller Road Bangalore 560 052
	Kirloskar Electric Co Ltd Unit-IV, Belawadi Indl Area Mysore 510 005
	Siemens Limited Jyothi Mahal, III Floor -49 St Marks Road, Bangalore 560 001
	Allen Bradley Ltd C-11, Site-4 Industrial Area, Shahibad Pin 201 010
Soft Starters	Jeltron Instruments (I) (P) Ltd 6-3-248/F Road No 1 Banjara Hills Hyderabad 500 034
	Jayshree ElectroDevices (P) Ltd 101, Prabhodhan Apartment 64/9, Erandewane, Pune 411 004

Appendix - 13/1 contd.

Eqpt./Retrofit	Manufacturer
Energy Efficient Motors	Siemens Limited Jyothi Mahal II Floor St Marks Road, Bangalore 560 001
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Soft Starters	Jeltron Instruments (I) (P) Ltd 6-3-248/F Road No 1 Banjara Hills Hyderabad 500 034
	Jayshree ElectroDevices (P) Ltd 101, Prabhodhan Apartment 64/9, Erandewane, Pune 411 004

Appendix - 13/1 contd.

Eqpt./Retrofit	Manufacturer
Insulating Material	Lloyd Insulation Pvt Ltd H-13, Connaught Circus New Delhi 110 003
	Hyderabad Industries Ltd Sector 25, Faridabad -121 004 Haryana
	Orient Cerawool Ltd 5, Basement, Dalamal Towers Nariman Point , Bombay 400 021
	Taylor Instruments Co (I) Ltd 14, Mathura Road P O Amar Nagar, Faridabad
	Industrial Business Associates Shop No 6, Ratan Sadan Sane Guruji Road Jacob Circle, Bombay 400 063
Water Flow & Oil Flow Meters	Kent Meters Ltd Agent : L & T Limited Gulas Bhavan 6, Bahadur Shah Zafar Marg New Delhi 110 002
	Eureka Industrial Eqpmt Pvt Ltd 258, Kalina Udyog Bhavan Prabhadevi Bombay 400 025
	Rojaram Consultants A, 5 Surabhi Apartments 21, Abhiramapuram, I Street Madras 600 018

Appendix - 13/1 contd.

Eqpt./Retrofit	Manufacturer
	SS Engineering Industries H-5, South Extension Part I, New Delhi 110 049
	Rockwin India E 1/7, Vasant Vihar New Delhi 110 057
Automatic Damper Control for CO_2	JNM Systems & Services P B No 37 Bombay-Pune Road Kasarwadi Pune 411 055
	Taylor Instruments Co.(I) Ltd 14, Mathura Road P O Amar Nagar Faridabad
	Industrial Business Associates Shop No 6, Ratan Sadan Sane Guruji Road Jacob Circle, Bombay 400 063
Power Analyser (To measure kVA, kW, PF, V & A)	Microtek Instruments 40-A, I Main Road I Floor, CIT Nagar Madras 600 035
Blowers	S M India Limited 42-A, Harrington Road Madras
	Andrew Yule Co Ltd Engg Division Yule House, Clive Road Calcutta 700 001

Appendix - 13/1 contd

Eqpt./Retrofit	Manufacturer
	Flakt India Ltd P B No 107 Bangalore 560 052
Lux Meter	Cocin Prakrito Instrumentation 16, Rajendra Nagar P O Mohan Nagar Ghaziabad 201 007
Anemometer	Microtech Instruments 40-A, I Main Road CIT Nagar, Madras 600 035
O_2 & CO_2 Analysers	J N Marshall Systems & Services P B No 37, Bombay Pune Road Kasarvadi, Pune 411 005
	Taylor Instrument Co (I) Ltd 14, Mathura Road PO Amarnagar, Faridabad
Star Delta Auto Controllers	Project & Supply A-605, Sunswept, Lokhandwala Complex Swami Samarth Nagar Four Bunglow, Andheri (W) Bombay 400 056
	Technovation Control & Power Systems 5, Savita Sangam Society Near Rajesh Apartment, Gotri Road Baroda 390 007
Compact Fluorescent Lamps	GE-Apar Lighting Maker Chambers 111, I Floor Nariman Point Bombay 400 021

Appendix - 13/1 contc

Eqpt./Retrofit	Manufacturer
	Crompton Greaves Ltd. Lighting Division Dr E Moses Road Worli Bombay 400 018
Compressors	Kirloskar Pneumatic Co Ltd Industrial Estate Hadaspur, Pune Maharashtra
	Ingersol Rand (I) Ltd Rhome-Poulence House S K Ahiri Marg PO Box 9138 Bombay 400 025
	Hindustan Compressors Ltd 18-A, New Market Begum Bridge Meerut 250 001
	Elgi Compressors India House, Trichy Road Coimbatore 641 018
	Consolidated Pneumatic Tool Co Ltd 301-302, L B Sastri Marg Mulund, Bombay 400 001
	K G Khosla Compressors Ltd 1, Deshbandhu Gupta Road New Delhi 110 055
Fyrite Kit For CO_2 Measurement in Flue Gases	J N Marshall Pvt Ltd Kasarwadi, Poona 411 034 Maharashtra

Appendix - 13/1 contd

Eqpt./Retrofit	Manufacturer
Moisture Separators for Compressed Air (Automatic drain valve)	Trident Industries 408, Sathy Road Ganapathy Coimbatore Mktd by Trident Electric Pvt Ltd # 133, I Floor, 11th cross Opp Jeerige Bldg Malleswaram, Bangalore 3
	Prasad Machine Works 8/85, Nehru Nagar PO Kalaputti Coimbatore 641 035
	Siemag Hi-tech Filters Pvt Ltd # 7, New Lata Apartments Jawahar Nagar, Goregaon (W) Bombay 400 062
	Mercury Automatic Corpn 8712, Arangung Near Palace Cinema Roshanera Road Delhi 110 007
Cooling Towers	Paharpur Cooling Towers 81/B, Diamond Harbour Road Calcutta 700 027
	Mihir Engineers Pvt Ltd 3rd Floor, Dr D N Road G P.O Box No 1389 Bombay 400 011
Steam Traps	Harfort Manufacturing C-204, Akshay, Y A C Nagar Kondivita Road, Bombay 400 059

Appendix - 13/1 contd

Eqpt./Retrofit	Manufacturer
	Uni Klinger Ltd Liberty Building Sir Vittal Thakersay Marg Bombay 400 020
	Hawa Engineers Pvt Ltd 29-A, Highway Commercial Centre Dani Limda, Ahmedabad 380 028
Digital Thermometer	Radix A/34, 2nd Floor, Ghanshyam Indl Estate, Off Veera Desai Road, Andheri (West) Bombay 400 058
Low Cost Photo Cell Timer	Govt Tool room Training Centre, Electronic Section, Rajajinagar Indl Estate, Bangalore 560 044
Voltage Controllers	Beblec (India) Ltd 126, Sipcot Complex Hosur 635 126,
	Electronics India 238/A, 10th Main Road Nagendra Block, BSK II Stage, Bangalore 560 050
FRP Blades Fans for Cooling Towers	Parag Fans & Cooling Systems Ltd Plot No 1/2-B & 1-B/3A, Indl Area # 1 A B Road, Dewas - 455 001 (M P)

TATA ENERGY RESEARCH INSTITUTE
BANGALORE

August 8, 1997

From H.V Dayal
Dean & Sr. Fellow

To. Mr K.Rajagopal (PMU)
TERI, Delhi.

Dear Mr Rajagopal,

Enclosed please find final copy of Comprehensive Energy Audit Report conducted for Chemfab Alkalis Ltd., Pondicherry.

Please confirm receipt of the above.

Best wishes,

f. P.R. Kumar

(H V DAYAL)

Encl As above

Copy to Dr R K Pachauri
Director - For information please

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